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Contents

73 • Rapid Expansion of the Maxillary Dental Arch and Nasal Cavity by Opening the Midpalatal Suture
Andrew J. Haas, D.D.S., M.S.

91 • Evaluation of Cervical Anchorage Force in Treatment
S. J. Klocbn, D.D.S.

105 • The Soft Tissue Profile, Growth and Treatment Changes
J. Daniel Subtelny, D.D.S., M.S.

123 • Highlights in Recent Foreign Literature
Arthur H. Craven, D.D.S., M.S.

132 • Function and Growth
John R. Thompson, D.D.S., M.S.D., M.S.

The material for this issue was presented at the organizational meeting of the University of Illinois Orthodontic Society. This meeting was dedicated to William B. Downs, a member of the first class — "a devoted teacher, constant student, and sincere friend".

Rapid Expansion Of The Maxillary Dental Arch And Nasal Cavity By Opening The Midpalatal Suture

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INTRODUCTION

Orthodontic and rhinologic literature from 1860 to about 1930 reveals considerable controversy over the desirability and possibility of splitting the hard palate at the midsagittal suture as a means of widening the dental arch and the nasal cavity. The findings in this paper are based on two rather distinct sources; the first, an animal study at the University of Illinois[19]; the second, a group of patients selected from the author's private practice.

The animal study was designed to determine if the midpalatal suture could be opened and, if so, to what extent. Also what would be the attendant effects of such an operation on contiguous oral and nasal structures? Another question suggesting itself was, "What, if anything, occurs in the mandible coincidentally with the maxillary changes?"

Based on certain encouraging findings produced by the animal study, it seemed logical to attempt to extend these benefits to those cases of malocclusion that require more than orthodontics, namely, facial orthopedics. Those cases where it was desirable or almost imperative to alter the denture base, if successful treatment was to be attained, formed the basis for selection of the clinical cases.

REVIEW OF LITERATURE

The contracted maxillary arch has always been of major concern to those men who have interested themselves in the regulation of the teeth and the rapid expansion of this arch by forceful separation of the maxillae has been discussed for almost one hundred years. The first reference to the procedure that the present writer could discover was that of E. H. Angell[1] in 1860. He fashioned a jackscrew across the roof of the mouth of a fourteen year old girl with its ends bearing against the first and second bicuspids of one side and against only the second bicuspid on the other. The patient was directed to turn the nut of the jackscrew twice daily. Angell described the results as follows: "These directions were industriously followed and at the end of the two weeks the jaw was so much widened as to leave a space between the front incisors . . . showing conclusively that the maxillary bones had separated, while the left lateral incisor (previously in cross-bite) had been brought completely outside of the anterior teeth." An editorial by J. H. McQuillen which accompanied the article was prophetic of the arguments that repeatedly were to be raised against the operation: "With no disposition to assert that such a thing is utterly impossible, yet taking into consideration the anatomical relations existing between the right and left superior maxillae and the other bones of the face with which they articulate, such a result appears exceedingly doubtful. Even admitting the impression of the writer to be correct, it would be a very strong

argument against the use of such an apparatus, for surely the irregularity of the teeth is a trifling affair as compared with the separation of the maxillae, which could not take place without inducing serious disturbance in the surrounding hard and soft parts."

The procedure was, nevertheless, attempted with varying success by Farrar (1888), Goddard (1893), G. V. Black (1893), Monson (1898), G.V.I. Brown (1903), Ottolingui (1904), N.M. Black (1909), Landsberger (1910), Willis (1911), Wright (1912), Barnes (1912), Hawley (1912), Pullen (1912), Schroeder-Bensler (1913), Dewey (1914), Huet (1926), and Mesnard in 1929. Following this there was an almost complete abandonment of the method, at least in the United States, which was probably due to the widespread acceptance of a functional concept of development.

This concept held that, if the teeth were gently moved into their proper relations by conservative orthodontic means and if vigorous function followed, bone would grow to support them. Further than this, it was believed that such a widening of the dental arch resulted in an increase in the width of the nasal passages.

In spite of frequent failures to attain these objectives, such methods remained popular and almost unchallenged until 1938 when the staff[6] of the Department of Orthodontics, University of Illinois, published the findings of an x-ray appraisal of treated orthodontic cases. Among the conclusions drawn from that study appeared the statement: "Actual bone changes accompanying orthodontic management seems to be restricted to the alveolar process." Since that time repeated investigations of a similar nature have verified the observation that changes induced by orthodontic methods in the dental arch and in the alveolar process which holds them do not extend into the supporting bone. This means that there is no accompanying change in the nose.

Recently Moore[29] has suggested the possibility of changing the facial pattern by utilizing extraoral anchorage. Ricketts[33] has strongly stated his belief that extraoral anchorage can actually cause the entire maxilla to be moved posteriorly.

The appliances that have been employed by various men for the rapid separation of the maxillae have differed mainly in their methods of attachment to the teeth. Angell, as has been noted, merely fashioned a jackscrew between the teeth of the opposite sides of the mouth, probably by first making small pits in the teeth to receive the ends of the jack. Others have banded teeth and fastened the jack to the bands and still others have employed split plates of vulcanite rubber with bands and jack embedded in them. The principle is the same in all and each is capable of exerting great force.

Nearly all of the reporters who have employed the method have commented on the separation which appeared between the central incisors. In not a few cases this has been the cause of alarm and the treatment has been discontinued promptly.[17, 20]

Others have disregarded this separation and continued to use the technique. They have failed, however, to comment on the subsequent behavior of the separated teeth. Recently, it has been shown by Derichsweiler[13] and Korkhaus[23,24] that the teeth drift together again quite rapidly following their forced separation, even while the two maxillae are held apart. A number of writers have claimed that new bone formation filled the space between the separated maxillae, and this has been verified by both dissection and x-ray.[5, 12, 13, 15, 23, 24]

According to Pfaff,[31] Lohman,[26] and Derichsweiler,[13] the first rhinologist to be interested in the separation of the maxillae was Eysell of Berlin, who, in 1886, suggested the possibility of influencing the inner conformation of the nose in this manner. He apparently met with complete skepticism on the part of his confreres and gave up the idea.

In 1903, G.V.I. Brown advocated the method for the specific purpose of obtaining greater nasal width. Brown wrote, "By the aid of pressure which is so gently applied that there is no pain and but little inconvenience, it is possible in all young persons to force the maxillaries apart by separating the median suture extending between the central incisor teeth and through the central part of the hard palate." Evidence of this was given by the fact that the central incisors were moved apart without any attachment to them or by any direct pressure being applied to them. Wright[37] made intranasal measurements on over thirty patients treated for nasal insufficiency by rapid expansion procedures. He measured the distance between antral walls below the inferior nasal concha and found increases up to 6.5 mm. All showed increases in width and from slight to marked improvement in intranasal respiration. Following Brown's method, Willis[36] reported a case of a female unable to do physical work because of difficulty in breathing. Using Brown's technique he separated the maxillae in three weeks to a distance that allowed the passing of a lead pencil barrel between the central incisors. Illustrations of plaster models verify this.

Derichsweiler[13] and Korkhaus[23],[24] have described the rapid spreading of the palatal suture on patients in their practices. The report of Derichsweiler is based on eighty cases and covers not only the separation of the maxillae and the central incisors but also the deposition of bone at the suture, the expansion of the nose and the descent of the hard palate.

Debbane[12] in a recent radiographic and histologic study of the effect of orthodontic expansion of the midpalatal suture of the cat employed continuous and intermittent intercanine forces for a period of sixty-three to seventy days. He found increases in intercuspid width ranging from 4.5 mm to 8.5 mm. The maximum opening of the midpalatal suture however was only 0.7 mm between the premaxillary bones, decreasing to zero in all cases between the palatine bones. These findings closely parallel those obtained by Dewey[14] on dogs and seem to indicate that the carnivorous type of dentition is particularly adapted to withstand lateral pressure.

Material and Method in the Animal Study

The specimens used in the animal study were eight seven and three-fourths month old Duroc-Poland China pigs. They were litter mates weighing approximately one hundred and fifty pounds at the start of the study and two hundred and twenty-five pounds at completion, twelve weeks later. Six animals were designated as experimental, two as controls. The pig was chosen because it is an omnivore and able to withstand the experimental conditions of the study. It was further believed that animals of that age and size would have attained much of their ultimate jaw growth in width. The findings of the study were based on—

1. serial plaster casts of the jaws
2. vital staining of the bones
3. coronal serial cephalometric roentgenograms
4. embedded and sectioned tissue blocks
5. dissection of wet tissue specimens.

The appliance was an acrylic split palate with a jackscrew across the midline. It was anchored by posts inserted into deep pits prepared on the lingual surfaces of four teeth on each side of the dental arch. The appliances were expanded 1.8 mm each adjustment. Seven or eight adjustments were made over a ten day period giving about 12 to 15 mm of total extension.

Dental casts and serial cephalometric roentgenograms were made before, during and at completion of appliance manipulation. Alizarin injections were given after appliance regulation at four, fourteen, and thirty day intervals. Portions of the maxilla were embedded in polyester resin and sectioned. Others were dissected in the wet state and photographed.

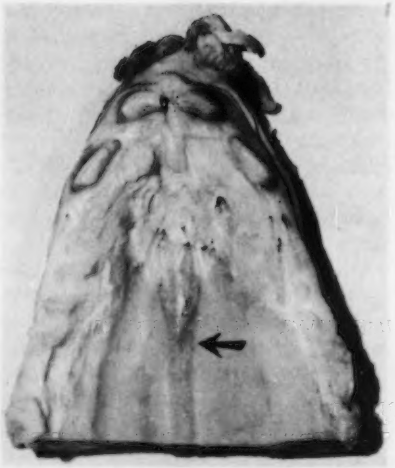

Fig. 1 This specimen shows the typical staining effect on the midpalatal suture in the experimental group. Note the deeply staining core of new bone with the old suture margins being delineated by white lines of resorption.

Findings in Animal Study

General The animals gave little or no indication of pain during the tightening of the screw and following the initial adjustment the maxillae offered little resistance to spreading. The opening of the suture was detected by passing needles through it and also by laying back a flap of palatal tissue for direct observation.

Dental Casts Increases of up to 15 mm in upper arch width were recorded in less than two weeks. The mandibular teeth tended to follow the maxillary teeth expanding without any direct appliance force.

Wet Specimens In the alizarinated specimens the new bone growth in the suture stained very deeply, while resorbing spines on the margin of the old suture easily delineated this new increment of bone. This bone was formed rapidly, completely bridging the gap in five weeks in one of the animals (Figure 1). Specimens obtained from animals sacrificed soon after expansion demonstrated considerable spacing of central incisors. Specimens of those sacrificed at a later date revealed that these spaces closed rapidly by tipping of the incisors toward the midline. Early opening of the suture was scissors-like in nature, while force continued for a longer period of time produced a more parallel opening.

Embedded Tissue Blocks Sections of experimental animals showed a marked thickening of the nasal septum at its articulation with the palatal crests of the maxillae. They demonstrated a bending of the alveolar processes with a lowering of the palatal vault. The teeth receiving the force of the appliance were tipped laterally (Figure 2).

Cephalometrics Coronal headplates of the experimental animals revealed some dramatic changes. These changes were recorded by making interconchal measurements across the fourth premolars (Figure 3). Internasal width increased up to 7 mm in one case. In another, 3

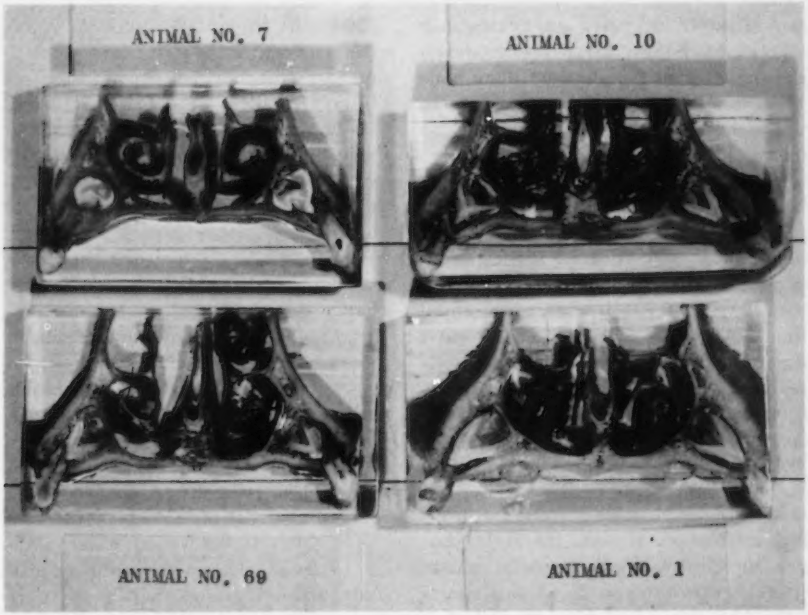

Fig. 2 Embedded tissue blocks of a control animal (No. 7) and three experimental animals show corresponding cuts through the first premolar region. Note the difference in the proximity of the plane to the palate. Further note the increased width of the base of the nasal septum formed by the palatal crests of the maxillae in the experimental animals.

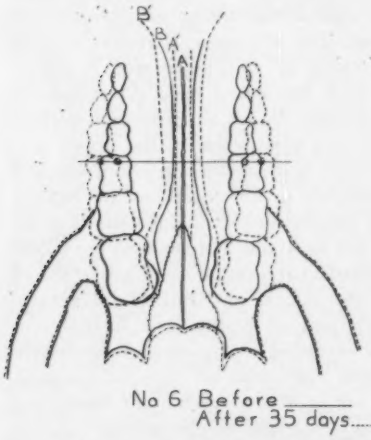

Fig. 3 Tracings of serial coronal headplates of an experimental animal superimposed on the vomer and registered on a line through images of amalgam implants. Note the increase in palatal width as well as the lateral movement of the shadow of the inferior concha (B, B') and suture margins (A, A').

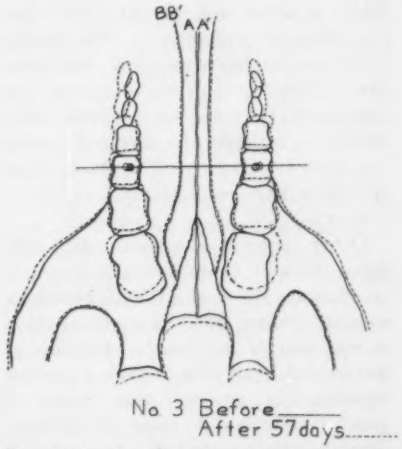

Fig. 4 Tracing of serial coronal headplates of a control animal superimposed as in Fig. 3. Note the slight increase in arch length and in the forward growth of the maxilla to gain space for second molars while the shadows of the inferior concha B, B' remain stable.

mm of intranasal space was achieved in forty-eight hours. Over a fifty-seven day period in one of the control animals (Figure 4) there was an increase in upper arch width of 3.6 mm yet no measurable change in nasal width.

The general conclusion that seems to be indicated by this investigation on pigs is that the midpalatal suture can be opened to a degree sufficient to cause a significant widening of the maxillary dental arch while at the same time increasing intranasal capacity. Further, the mandibular dental arch will expand a significant amount in response to altered natural forces.

Clinical Study

Material and Method

With courage gained from the findings in the animal study the author began to selectively use a similar palate splitting operation in his clinical practice. The animal study indicated that this procedure might be of particular value in treating cases of severe maxillary compression where teeth are already in labial and buccal inclination and even in crossbite of the buccal teeth due to inadequacy of the bony base. This type of malocclusion has long been one of the greatest challenges in orthodontic therapy; unless the patient enjoyed extraordinary growth it has usually been doomed to relapse.

Other patients who seemingly could derive benefit from midpalatal suture opening are the severe mouth breathers who are seldom aided by anything short of resection of the concha. Examining the frontal head film of such a patient demonstrates among other things a very narrow nasal aperture literally filled by the concha crowding against an often deviated septum. Increasing intranasal capacity should facilitate nasal respiration and thus contribute to better general health.

It seems logical that such a procedure would give the clinician a tremendous assist in the treatment of his most difficult problem—the Class III case. Consider the advantage of correcting the usual bilateral crossbite associated with these cases in several weeks time.

The clinical aspect of this study involves the author's experience in the treatment of forty-five patients with maxillary or nasal insufficiency. Appliance design, rate of screw manipulation and objectives varied in many of these cases. Ten cases were selected for this report as they represented a similar purpose in treatment objectives, appliance design and screw manipulation. Five cases are male and five are female. The youngest patient was nine years of age; the oldest was eighteen.

The areas chosen for study were similar to those examined in the animal study, namely, the changes induced in the maxilla, nasal cavity and mandible.

Observations were made on frontal and lateral cephalometric headplates, dental casts, photographs, and from patients' comments on subjective symptoms. The appliance that was used in effecting the splitting is seen in Figure 5. It is fabricated by a direct-indirect technique. Bands are made, or selected for, and positioned on the upper permanent first molars and either the first premolars or the deciduous first molars. An impression is made, the bands transferred to it and a stone working model poured. Connecting bars are soldered to the buccal and lingual surfaces of each pair of bands. The lingual bars are extended anteriorly and posteriorly. These extensions are directed palatally to act as lugs to anchor the bands and bars to the split acrylic palate.

An expansion screw is mounted on a piece of base plate wax perpendicular to the long axis of the screw. The base plate wax is trimmed to conform to the contour of the palate in order that the

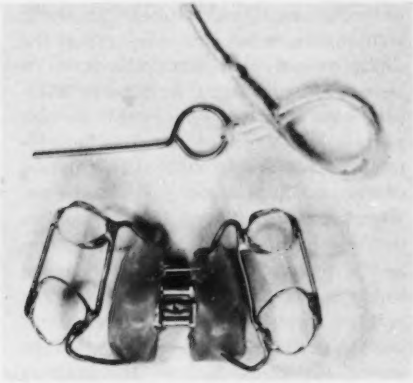

Fig. 5 Pictured is a fixed split palate appliance as it appears at stabilization. The .040 bar anterior to the screw was added when enough palatal width had been attained. At the top of the picture is the key that is used to turn the screw.

center of the screw lies directly over the midline and the lateral margins of the screw are raised about a millimeter from the palate. Elimination of the wax at a later stage gives the needed split in the appliance. Quick cure acrylic is applied to the cast by a dust-on method and built up to cover the screw and the anchor lugs of the lingual bars. The appliance is then separated from the stone model and trimmed making sure that all edges and corners that will contact palatal mucosa are well rounded.

An acrylic body is preferred rather than an all wire framework as much of the expanding force is exerted against the alveolar process and base bone rather than just teeth. Since the horizontal force of the screw against the inclined lateral walls of the palate would tend to displace the appliance, it would seem that if maximum suture opening is to be realized the appliance must be fixed. A removable expansion screw appliance will primarily tip teeth laterally.

Manipulation of Appliance

Most expansion screws available today are calibrated to give 0.8 to 1 mm extension for each full turn of the screw. The construction of the screws is such that they must be turned a quarter turn at a time.

The technique that has given the author the most consistent results to date is as follows: after the appliance has been cemented, the screw is given one full turn over a fifteen minute period, a quarter turn each five minutes. A parent should be permitted to make the final turn to be certain he or she will understand the procedure. To avoid accidental swallowing or inspiration of the key a string should be attached to it and the parent instructed to wrap or loop the string about the fingers. For ease of manipulation, in construction the screw is so oriented that the key to operate it is inserted anteriorly and moved in a posterior arc.

The parent is instructed to turn the screw a quarter turn in the morning and a like amount in the evening. The patient is observed at approximately 7, 10, 14, 18, and 21 day intervals and the screw manipulation is discontinued when sufficient palatal width has been attained. As in many orthodontic procedures it seems best to overtreat to allow for subsequent uprighting of tipped teeth and recontouring of bent alveolar process.

To prevent the screw from turning back during function the appliance is stabilized the same day manipulation is stopped. A disc or bur is used to score both separated acrylic masses and a piece of .040 wire is fastened into these grooves across the palate with a dab of quick cure acrylic. The appliance is permitted to remain in place for approximately three months acting as a retainer to allow bone to be formed in the opened suture. The appliance is then removed and at the same sitting an acrylic palate processed from quick cure acrylic is inserted. The acrylic pal-

ate is subsequently worn throughout treatment and retention.

Lateral and frontal cephalometric headplates, intraoral occlusal films, intraoral photographs and dental casts were made just before the palatal splitting procedure began, at the time the appliances were stabilized to act as retainers, and again when the appliances were removed. Radiographic records are subsequently made on a check up basis until the case is completed.

Clinical Findings

The patients rarely complain of discomfort. Inquiries made into subjective symptoms elicit astonishingly consistent replies even while making an effort not to influence these replies. There is virtually unanimous agreement that the slight pressure felt when the screw is tightened is dissipated in minutes. Pressure is almost always felt at the alveolar process and vault of the maxillae, almost as frequently at the articulation of the maxilla, frontal and nasal bones. About half the patients cite pressure at the zygomaticomaxillary suture areas and a few at the zygomaticotemporal suture areas.

These pressure syndromes can be ascertained at the observation visits by giving the screw one or two quarter turns and asking the patient to point to the areas where pressure is experienced. Patients will usually notice from slight

Fig. 6A

to marked improvement in nasal respiration depending on the severity of the nasal stenosis at the start of therapy. Those with the greatest degree of respiratory difficulty seem to notice the most improvement.

The soft tissue which lies immediately beneath the acrylic split palate presents a varied reaction to the operation. If in construction the appliance is carefully finished by rounding all edges of acrylic, the response of the tissue is good. At best no hypertrophy occurs; at the worst a moderate amount may occur, a reaction similar to that found in conjunction with the use of a Nance type palatal holding arch. If one is willing to accept the disadvantages attendant to applying all force directly to the teeth with an all wire framework, soft tissue response is uneventful.

Frontal Headplate Finding

The frontal headplates present some of the most interesting findings associated with this study. Figure 6A and 6B are frontal headplates made before and after opening the midsagittal suture on a twelve year old male. In this particular case an 8 mm void was created between the maxillae at the intermaxillary suture. The nasal cavity was widened 4.5 mm and the unerupted third molars also demonstrated a 4.5 mm expansion. Serial frontal headplates for each patient were traced. Parallel vertical tangents were constructed to the points of greatest convexity on the lateral walls of the nasal aperture, the second or third molars,

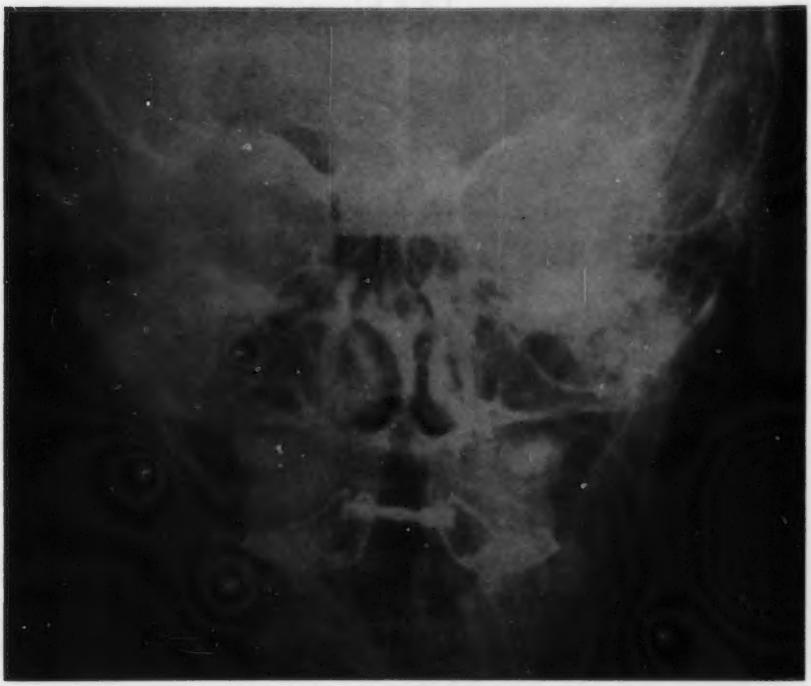

Fig. 6B

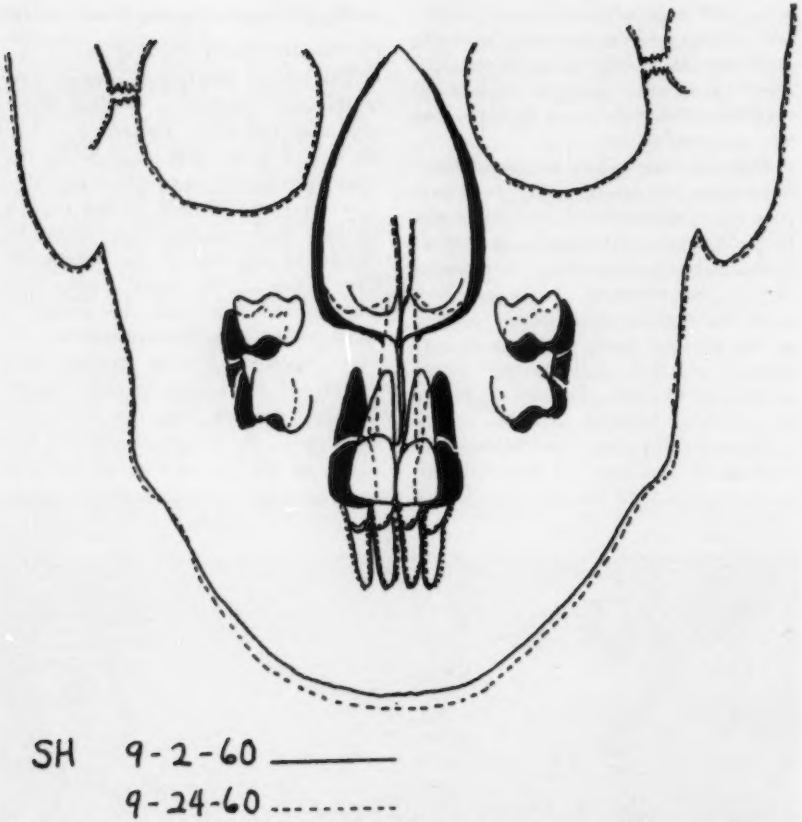

Fig. 7 A tracing of serial frontal headplates of a twelve year old male demonstrating a marked change in maxillary width over a twenty-two day period. The tracings were superimposed over cranial and mandibular outlines.

and the central incisors. A lineal measurement was then taken across each pair of tangents to record changes in nasal, intermolar, and interincisal width. The width of the suture opening can be measured directly and at various levels, e.g., between the palatal crests of the maxillae or at prosthion.

Two such tracings excluding the constructed tangents are superimposed in Figure 7. Note the marked maxillary and nasal changes occurring in twenty-two days. These changes are numerically recorded in Tables I and II. The shortcomings of making lineal measurements on the frontal headplates are realized. However, these measurements were made on or near midline structures and none were of a vertical nature. Also the remarkable consistency of these measurements in a series would seem to indicate that the error is comparable in all films of a series; thus the measurements have value on a relative rather than an absolute basis which is all that is intended.

TABLE I

Changes in Maxillary Width Following Opening of the Intermaxillary Suture

	Start nasal-intermolar		Stabilization max. defect		Nasal-intermolar			Follow Up nasal-intermolar	
C. D.	28	60.5	(18)	6	32	66	(111)	32	65
S. H.	29	65	(22)	8	33.5	69.5	(107)	33	69
N. K.	30	58	(27)	6	32.5	62.5	(99)	32.5	62
L. W.	33.5	61	(18)	4.5	36	64.5	(122)	36.5	64.5
C. M.	28	57.5	(13)	4	30	59	(63)	30	59
S. W.	33	64	(20)	4	35	66	(256)	35	66
N. M.	32.5	60	(19)	3.5	35	62	(67)	35	62
D. B.	34	59.5	(28)	4	36	63.5	(49)	36	63.5
L. P.	36	64	(13)	4	38	68	(22)	38	67.5
J. W.	39.5	72	(12)	4.5	42	74.5	(464)	42.5	74.5

These ten cases illustrate the millimeter changes in nasal and intermolar dimension. The maxillary defect is a measurement of the void between the maxillae at prosthion at stabilization. The figures in parentheses indicate the number of days between taking headplates.

The explanation for the reaction of the central incisors to the spreading of the maxillae was the most challenging phenomenon in this study. (1) It was successively observed that the gap created between the central incisors was about one half as great as the distance the screw had been opened. (2) Tracings of frontal headplates demonstrated that the roots diverged a greater distance than the crowns during screw manipulation (Table II). (3) After manipulation ceased the roots continued to diverge while the crowns tipped toward the midline with a rapidity of movement suggestive of that seen in light wire therapy (Figure 8). (4) After the crowns drifted together the roots began to move medially so that the incisors eventually resumed original axial inclination (Figure 8, Table II). (5) This entire cycle, without benefit of unnatural forces, was completed in four to six months time even with incisors spaced as much as 8 mm after appliance manipulation.

Brodie[7] reiterated that bone should be considered to be connective tissue

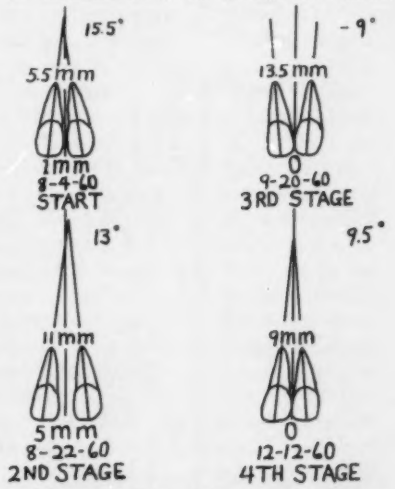

Fig. 8 These tracings show the action of the central incisors in case C.D. Note how the angle of inclination of the incisors changed from a +13° to a —9° in just twenty-nine days. In another fifty-three days it changed back to a +9.5°.

TABLE II

Changes in Central Incisor Posture Following Opening of the Intermaxillary Suture

	Start				Stabilization				Early Follow Up				Later Follow Up			
	root	crown	∠of inc.		root	crown	∠of inc.		root	crown	∠of inc.		root	crown	∠of inc.
C. D.	5.5	1	15.5°	(18)	11	5	13 °	(29)	13.5	0	-9 °	(53)	9	0	9.5°
S. H.	6	0	7 °	(22)	14	6	3 °	(59)	15	0	-13 °	(48)	9	0	0°
N. K.	8.5	3.5	13 °	(27)	13.5	8	10 °								
L. W.	8	0.5	5.0°	(18)	13	4	-1 °					(122)	11	0	-3.5°
C. M.	6	0	12.0°	(13)	10.5	2.5	5 °	(63)	12	0	-3.0°				
S. W.	6	0.5	8.0°	(22)	10	3.5	6 °	(48)	10	0	-3.0°				
N. M.	7.5	0	7.5°	(19)	12	3.5	3.0°	(67)	14	0	-3.5°				
D. B.	8	0.5	5.5°	(28)	12.5	3	2.0°	(49)	13.5	0	-7.0°				
L. P.	7	0	8.0°	(13)	12.5	3.5	0.5°	(22)	14	2	-4.0°				
J. W.	6.5	0	10.0°	(12)	12	4.5	7.5°								

These ten cases illustrate the tremendous activity occurring between the central incisors. Interapical and intercrown distances and changes in this distance are shown in millimeters. The angle of inclination is the angle formed by the long axis of each pair of central incisors. The figures in parentheses represent the number of days between taking headplates. No appliance of any kind ever touched the incisors during the time shown.

and not the unyielding structures we see in museums. He went on to hypothesize that orthodontic therapy might cause tensions in remote parts of the bone; recently he[8] labeled one of these forces the transeptal fibers. These fibers are visualized as an integrated chain of periodontal-like fibers lying at a level somewhere below the gingival fibers and linking all the teeth in the dental arch together. The behavior of the central incisors in this study strongly suggests the existence of transeptal fibers with perhaps the presence of an elastic element.

Assuming the existence of these fibers the action of the central incisors might be explained as follows. (1) As the maxillae separated, the crowns of the central incisors began to move laterally and the transeptal fibers across the midline began to stretch. (2) Since these fibers are probably in the area of the lower third of the root, their pull causes the crowns of the incisors to start tipping medially while the roots begin diverging laterally with the fulcrum of this action being approximately in the middle third of the root, (Figure 8, Stage 2). (2) After appliance stabilization the continued action of these fibers causes the crowns to tip very rapidly toward the midline with the roots moving almost as fast laterally. Lineal measurements in Table II indicate the relationship between time and distance the crowns and roots move and the change in inclination of the incisors to each other. Figure 8, Stage 3 indicates the marked change in axial inclination which can occur in as little as four weeks. The fulcrum for this phase of the phenomenon is located closer to the root apices than during the time the screw is being extended. (3) When the crowns approximate, the class of leverage changes; the contracting crowns now become the pivot and the force of the tensed transeptal fibers causes the roots to move medially toward their original position.

The frontal headplates also underscore the dramatic opening of the intermaxillary suture as witnessed by the void extending from the medial incisal edge of the central incisors superiorly through the articulation of the palatal crests of the maxillae and vomer. Table I indicates the width of this maxillary defect at stabilization. Subsequent headplates and occlusal films indicate that this defect is usually completely calcified in ninety days (Figure 9).

The obvious nasal result of spreading the maxillae is to increase internasal capacity. Table I establishes changes in nasal width ranging from 2 mm to 4.5 mm in from twelve to twenty-seven days of treatment. Succeeding frontal headplates demonstrate the remarkable stability of the increments of added nasal dimension. Changes in maxillary width were assayed by measuring between unerupted second or third molars (if the latter were present). The greatest increase in intertooth dimension was 5.5 mm, the least 1.5 mm. The intermolar change shows the same stability as does the internasal change. All the cases reported in Table I are still in retention. The data in Table I would also indicate that the opening of the intermaxillary suture is triangular in appearance with the base being toward the incisors and the apex in the nose. Most patients evince a similar pattern as case C.D. where the most inferior measurement of the maxillary defect at prosthion is 6 mm, the next highest across the molars is 5.5 mm and the most superior between the lateral nasal walls is 4 mm.

A measurement of the gap created between the palatal crests of the maxillae can also be used to determine the increase in nasal width; however, this area is later obscured by the healing process.

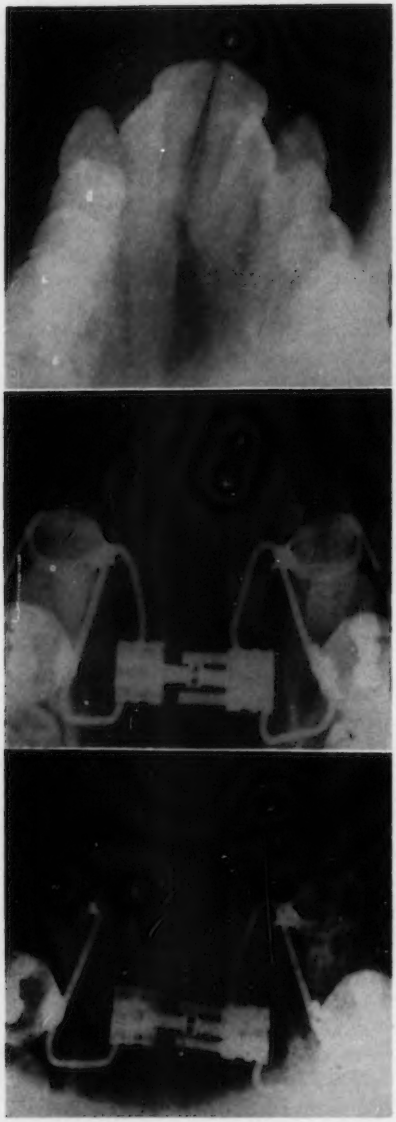

Fig. 9 (upper) is an occlusal exposure made prior to placement of the split palate appliance. (middle) The same patient twenty-one days later showing the large void created at the midpalatal suture. (lower) One hundred and seven days later showing complete calcification of the area.

The behavior of the maxilla was further scrutinized on tracings of the lateral headplates made before appliance placement and at stabilization, (Figure 10). The reaction of point A was of immediate interest. In all cases it moved forward and in five cases moved downward as well. Table III verifies this occurrence. Increases in the angle of convexity ranged from 1.5° to 8°, point A to facial plane measurement increased from 1 to 4 mm, and increases in angle SNA varied from 0 to 2.5°.

The tracing in Figure 10 raises the question of whether the increased severity of the Class II condition was not too much of a price to pay for the gain in arch length and greatly increased nasal ventilation. The angle of convexity increased 7°, point A to facial plane 4 mm and angle SNA 2°.

The answer may be provided in Figure 11 which indicates that during the four months following the splitting procedure, without any other appliances being placed, the angle of convexity decreased 4°, the point A to facial plane reading decreased 2 mm and angle SNA decreased 1°. This would seem to indicate that, as the maxillae move laterally, marked activity and adjustment must be occurring at the sutures of the cranial and facial bones with which the maxillae articulate. As sutures open and bones slide, the maxilla is displaced forward and sometimes downward. During the retention period this activity continues toward re-establishing the former proximity of the bones.

The forward movement of the maxilla can be of great benefit in the treatment of Class III and psuedo Class III cases. Figure 12 demonstrates a change in the Downs[16] profile arc from slightly concave to slightly convex with the only treatment being the opening of the midpalatal suture. The al-

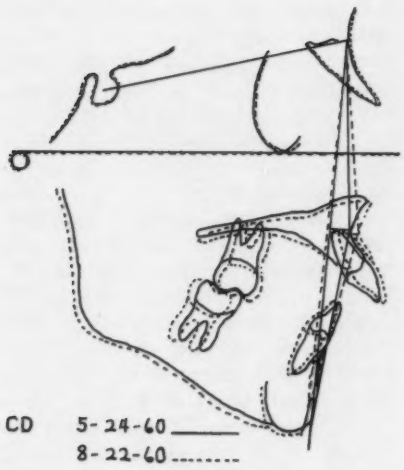

Fig. 10

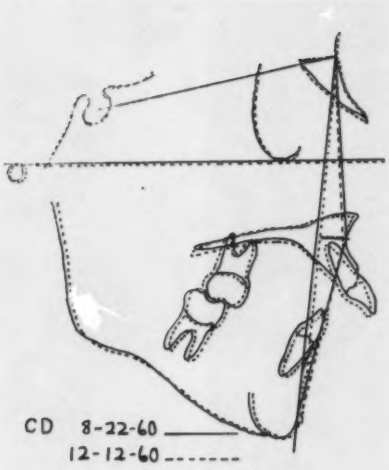

Fig. 11

tered position of the maxilla with concomitant disturbance of the occlusion also causes an opening of the bite with, of course, the corollary features of changes in mandibular plane angle and occlusal plane, posterior movement of pogonion and change in Y axis.

The response of the mandibular arch to splitting of the midpalatal suture was quite similar to that elicited in the animal study; namely, the mandibular teeth tended to follow the maxillary teeth by tipping laterally. Ten cases which had not received any treatment in the mandibular arch were selected. Intercanine and intermolar (first) widths were measured on the dental casts before treatment and for varying amounts of time after treatment. In all cases the intermolar width increased from a minimum of 0.5 mm to 2 mm. Five cases showed no change in intercanine width, while four had increases of 0.5 mm to 1.5 mm, and one case lost .5 mm. There is no direct relationship between time involved and the amount of change in arch width.

General Discussion and Conclusions

One of the most interesting findings in this study was the ease and extent to which the midpalatal suture can be opened. It was also surprising to find

TABLE III

	C.D.	S.H.	N.K.	L.W.	C.M.	S.W.	N.M.	D.B.	L.P.	J.W.
Convexity (deg.)	+7	+8	+3.5	+5	+5	+2	+3	+2	+3	+1.5
Pt. A to FP (mm.)	+4	+4	+2	+2.5	+2.5	+1	+1.5	+1	+1.5	+1
SNA (deg.)	+2	+2.5	0	+1.5	+1	+1.5	+1.5	+3.5	+1	+1.5

These ten cases illustrate the anterior displacement of the maxilla immediately after opening of the midpalatal suture ceased.

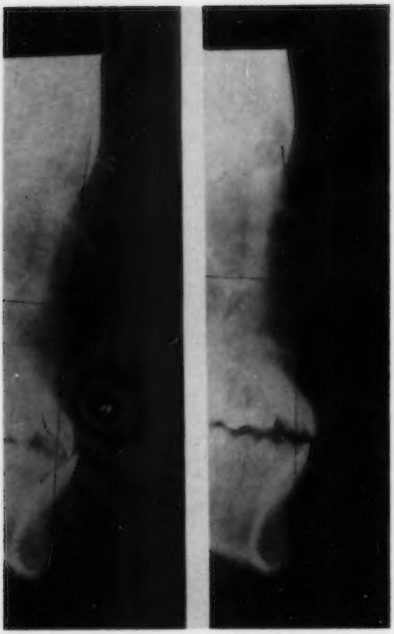

Fig. 12

an almost complete absence of pain. Derichsweiler,[13] Korkhaus[22] and others have commented on this lack of pain. Korkhaus reports the most common sensation to be pressure at the bridge of the nose.

Black[5] advanced the theory that, in addition to the separation, the palatine processes of the maxillae were also lowered as a result of the outward tilting of the alveolar processes. He felt that it was this action that resulted in straightening of the deviated septum. Brown[10] believed that when the suture opened the maxillae moved laterally and the deviated septum dropped down into the space between them. This study tends to support the former view. In addition to the lowering of the palatine processes it was apparent that as the suture opened new bone was laid down very rapidly; this would lessen the possibility of the septum occupying the space.

That the increment of arch width added by opening the midpalatal suture is permanent would seem to be assured through the repair of the defect by new bone. The permanency of the increment added by tooth movement and alveolar bending is questionable. Thorne[35] reported on twenty-eight cases subjected to opening of the midpalatal suture with a fixed split palate appliance. These cases were retained for varying amounts of time. Upon checking the stability of these cases one to two years after retention he found twenty-three cases showed either no change or an increase in the gained apical base and nasal cavity widths. The five cases which demonstrated a decrease in gained apical base and nasal cavity widths had very short retention periods.

Measurements and observations made from the various methods employed in the animal and the clinical study indicate that, as the screw is extended in a fixed split palate appliance, the earliest gross reaction is a lateral bending of the alveolar processes. This is followed by a gradual opening of the midpalatal suture. The palatine processes of the maxillae then begin to move inferiorly at their free margins to cause a lowering in the palatal vault. Possibly the bracing action of the zygomatic buttresses cause the separation between the maxillae to be wedged-shaped, with the apex of the wedge being in the nasal cavity and the base in the same plane as the palatine processes. The central incisors behave in a completely incongruous manner. Rather than follow their respective maxillae the roots diverge more than the crowns as the screw is opened. During stabilization the roots continue to diverge while the crowns converge. This action was interpreted as being due to the presence of tran-

septal fibers.

Baker[2] in research on the pig showed that arrested maxillary development resulted in marked mandibular deformity. In the present study it was found that the mandibular teeth tended to follow the maxillary teeth by increased buccal inclination. The significant increase of buccal tilt was probably due to a combination of several factors. The forces of occlusion were altered by the expansion so that the normal lingual vector of force on the mandibular buccal teeth was lost and the lateral movement of the maxillae widened the area of attachment of the buccal musculature. This resulted in a change of balance between the tongue and buccal musculature. As Brodie[7] observed, "The interaction of the forces of these two antagonistic muscle masses would dictate the size and form of the arches as well as the axial inclination of the teeth." A diminishing influence of the buccal musculature would permit the tongue to exert a relatively greater force from within, manifesting itself in an increased buccal axial inclination of the mandibular teeth as well as an expansion of the arch. There is also the possibility that the thickness of the appliance, which was up to three-fourths of an inch, caused a downward displacement of the tongue during rest as well as occlusion, thus increasing its lateral force on the mandibular buccal teeth.

This procedure has been most beneficial in the treatment of Class III and psuedo-Class III malocclusions, cases of severe maxillary compression (including some cleft palate patients) and patients with pronounced nasal insufficiency. The operation is by no means a complete treatment for any of these patients. However, having orthopedically moved the maxillae into a more favorable relationship with the mandible expedites the treatment of the patient. It reduces the amount of tooth movement necessary when fixed appliances are placed. The procedure not only results in an increase in dental arch width and hence its overall length but, also of equal importance, carries the attachment of the buccinator muscles laterally to a position where its crushing force on the mandibular arch is diminished. The latter would make judicious mandibular expansion a far safer maneuver.

In addition to these advantages must be mentioned the coincidental widening of the nose and lowering of its floor both of which, according to other authors, frequently make nasal breathing possible in individuals who have been habitual mouth breathers.

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Evaluation Of Cervical Anchorage Force In Treatment

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The introduction of the classification of malocclusion by Dr. Angle has frequently been credited for bringing order out of chaos in orthodontics. The order that was produced may be questionable, but the classification did provide a basis from which to start studies of similarities and variations and to provide better communication. The inferences and assumptions presented as facts for treatment planning and therapy based on classification impeded orthodontic progress almost as frequently as they stimulated. This was not primarily from any errors in the classification, but rather from the ever present concept of similarities of each classification with aims for providing rules to be followed blindly in treatment planning and appliance therapy.

For example, it was assumed the correction of a Class II malocclusion was successful when the maxillary and mandibular teeth were placed in correct alignment to each other and in correct interdigitation to their antagonists without much consideration about which teeth were moved and where. It was assumed appliance force, plus normal functioning relationship of the teeth, would stimulate growth of the mandible and the musculature providing the patient with the intended facial balance and denture stability.

The literature contains some evidence of such treated cases which were successful. However, a further analysis of the literature reporting frequent changes in appliances indicates all was not well. If necessity is the mother of invention, the failures in treatment must have been frequent because of the many changes. It is interesting to note that many changes in appliances were directed toward increasing stability of the teeth intended for anchorage and toward stimulating tissue changes around those teeth to be moved.

History is most valuable in guiding our thinking today as well as providing direction for our advances in the future. Unfortunately, most of us do not take time to acquaint ourselves sufficiently with the work of our predecessors, so well recorded in the literature. Ignorance of the past does not guarantee freedom from its imperfections, more probably it assures the repetition of the past errors. Practically all of the recent changes in appliances and therapy are merely reintroduction of similar methods used years ago including extraoral anchorage, light forces with long range, heavy forces with short intermittent reaction, heavy brackets and arch wires to produce strong torque force, light round arch wires with only tipping action and many gadgets. The work of early investigators and clinicians is to be complimented. However, many of their conclusions, favorable and adverse, need further investigation which can be done with greater accuracy with our more efficient methods and tools.

The cephalometric method of analysis has proven a most efficient tool for the study of normal and abnormal growth and for the study and observations of tissue response and changes resulting from various mechanical forces. It has focused our attention on

the many variations within the normal and abnormal, treated and untreated occlusions. Many studies and analyses have been made of the effects of treatment telling us which teeth were moved, how much, and where. Cephalometrics has provided facts and conclusions, some of which seem valid and others questionable. The method is accepted as being most accurate, but many interpretations are debatable leaving much confusion.

One need only study the many conclusions presented on the cephalometric studies of the past few years on extraoral anchorage treatment. There are some who demonstrated, most convincingly, the distal movement of maxillary teeth and the inhibiting of normal forward growth of maxillary teeth and alveolar process. There are others who claim to have evidence of retarding the forward growth of the entire maxilla. Some can report only holding the maxillary teeth while the mandible continues its forward growth. Several studies demonstrated no change in the relationship of the maxillary and mandibular teeth inferring that the method and appliance is ineffective.

All this might be most confusing and discouraging except for our knowledge of the many variables. This means variability in the size and ages of the samples, variations in the individuals studied, in the method of application of force and type of mechanical appliance; last and most variable is the method of analysis of the cephalometric tracings and measurements. The many conclusions presented direct our attention to the difficulty encountered, in a growing individual, of measuring movement of teeth by appliances.

Extraoral force applied with identical mechanics in the same direction and magnitude produces different results in different individuals. In studies where the sample was small and the results not so favorable, some investigators became critical of the method and recommended changes in appliances. For example, the assumption was made that the fixation of the arch and face bow produced an over-eruption or elongation of the maxillary molars and an undesirable change in the plane of occlusion. The correction of this was attempted by changing the union between the face bow and arch from a fixed union to one of a ball and socket arrangement or by advocating occipital anchorage to change the pull of the force in an upward direction in angles varying from thirty to fifty degrees. I have not found the elongation of the molars nor the opening of the bite a problem; a great many Class II malocclusions have a deep overbite in which increase of vertical dimension in the buccal segment is desirable.

There are open-bite cases which demand changes in treatment planning and appliance therapy. The orthodontist must recognize these and design his treatment and appliance accordingly. Recently, the statement was made that the tubes on the molar bands must be placed as close to the gingival portion of the band as possible to obtain the desirable tooth movement.

The opinions and assumptions increase when an extraoral appliance is used in conjunction with a full band appliance. There are too many to enumerate and, in my opinion, there is insufficient evidence to warrant analysis or discussion. Every patient and every malocclusion has variations which will produce different reactions to any given therapy. These many variations include the growth pattern of the face, the plane of occlusion, the functional stroke of the mandible, patient cooperation and last, but by no means least, the variation in construction of the appliance and the clinician's skill in adjustment and management of the

appliance and the patient.

I have not used cephalometrics for analyses of treated cases, therefore much depends upon clinical analysis with models and photographs. A good functioning occlusion with good facial balance is the goal in all orthodontic treatment with acceptable evidence for the method.

The essential requisite for successful treatment with any extraoral appliance is sufficient force, applied over sufficient time, in the desired direction. Thus the first requirement is a comfortable appliance which is acceptable to the greatest number of patients. The cervical appliance fulfills this requisite in my hands more frequently than any other extraoral instrument. The amount of force is determined by tissue and patient reaction; pain is the best indicator.

Cervical appliances are being used today for guiding growth, moving teeth distally and reinforcing anchorage. These applications will be demonstrated by the presentation of the following cases.

The upper models in Figure 1 are right and left views of a Class II, Division I malocclusion in a male, nine years of age. The analysis indicated good mandibular growth with favorable alignment and arch form. The mandibular teeth were in good relationship to the supporting bone and in balance with the musculature. The maxillary teeth were one full cusp mesial in their relationship with the mandibular.

The plan of treatment was directed toward placing the maxillary teeth distally into correct relationship with the mandibular without disturbing the position and balance of the mandibular teeth. The mandibular teeth served as the goal to which the maxillary teeth were to be guided and moved. Bands were placed on the maxillary right and

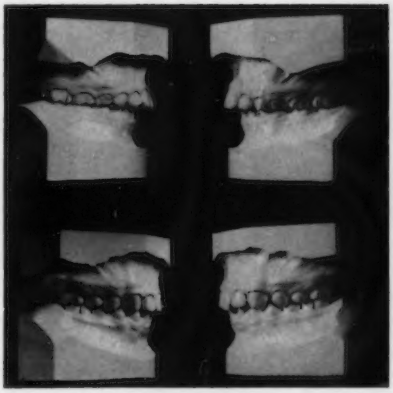

Fig. 1

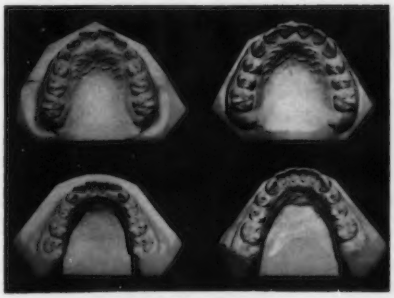

Fig. 2

Fig. 3

left first molars with cervical appliances to be worn seven nights a week, ten or twelve hours per night.

Lower models are right and left views taken three years and ten months later. All permanent cuspids and bicuspids are fully erupted and in good occlusion. The mandibular second molars are starting to erupt. The patient has excellent functioning occlusion with proper alignment of teeth and good facial balance.

This patient had bands only on the maxillary molars with a cervical appliance. Appliances were worn the last year to hold the molars while the cuspids and bicuspids were erupting into good functioning relationship. The time of wearing the appliance might have been reduced by waiting until the primary cuspids and molars were shed, but this is questionable. The chair time of the operator during cervical treatment with bands only on the maxillary molars is very short as compared with placing bands on the remaining teeth.

Figure 2 shows occlusal views before and after treatment. In Figure 3 are photos before and after treatment.

In Figure 4 (upper) are right and left views of a Class II, Division I malocclusion in a male, eight years of age. The facial growth has been acceptable. The mandibular arch was good with small open contacts in the lateral incisor, primary cuspid and primary first molar areas. There was some deficiency in vertical growth with the mandibular incisors functioning against the soft tissue of the palate. The maxillary teeth were mesial to the mandibular the width of one cusp with protrusion and open contacts of the maxillary incisors.

Treatment was planned to place the maxillary teeth distally into correct relationship to the lower teeth without changing the position of the mandibular teeth to their supporting structure. Bands were placed on the maxillary first molars with cervical appliance to be worn at night. A Hawley bite plate was placed after the maxillary teeth started moving distally to remove the interference of the mandibular incisors and to encourage vertical growth in the buccal segments.

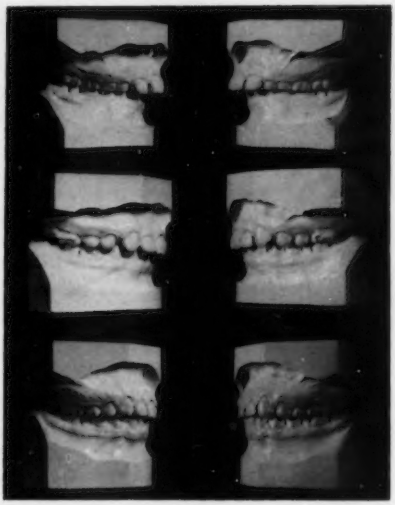

Fig. 4

Right and left views taken after one year and ten months of treatment with cervical appliance at night and about eight months of wearing a Hawley bite plate in the daytime are depicted in Figure 4 (center). The primary teeth have been replaced by their permanent successors and the molars and bicuspids are in correct functioning relationship with the maxillary molars farther distal than normal. Overtreatment of the molars is desirable to encourage better posterior movement of the bicuspids. The bite has opened but the maxillary cuspids and incisors have not moved distally and lingually sufficiently. There are open contacts between the cuspids and first bicuspids with a distal axial inclination of these teeth. The question arises, would treatment at an earlier age have permitted better distal move-

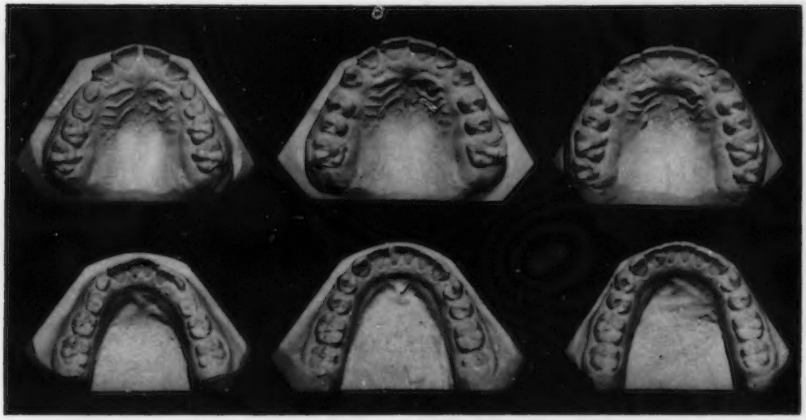

Fig. 5

ment of these teeth? This cannot be answered except by assumptions and opinions.

At this time edgewise bands were placed on the maxillary incisors and cuspids to move these teeth distally and lingually. Cervical appliance was continued on the molars to hold these teeth posteriorly while the rectangular arch was used on the incisors and cuspids.

Lower models (Figure 4) are right and left views after five months additional treatment.

The left models in Figure 5 are occlusal views before treatment; center models are occlusal views after one year and ten months of cevical appliance treatment, note open contacts between maxillary cuspids and bicuspids. On the right are occlusal views taken after five months of treatment with edgewise bands and a rectangular arch on the maxillary incisors and cuspids to close contacts and correct axial inclinations. The contact points in the mandibular arch closed without placing any appliance.

This patient had favorable growth with good facial balance (Figure 6). Clinically, there is considerable similarity between this case and the previous one. The cervical appliance treatment, to the best of my ability, was similar with equally good cooperation. The latter patient was one year younger chronologically, but his dentition was about two years older. He had all of his permanent teeth before his tenth birthday. These are variables which make it difficult to form a prognosis or definite rules regarding the most advantageous time of treatment.

Upper models in Figure 7 are right and left views of a Class II, Division I

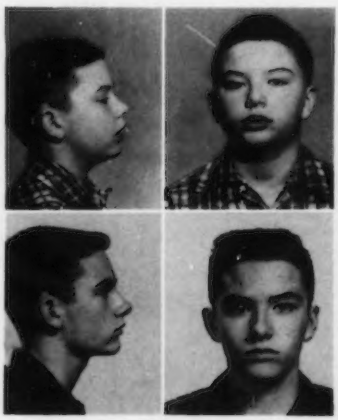

Fig. 6

Fig. 7

malocclusion in a female, twelve years of age. All of the permanent teeth had erupted except the right maxillary cuspid. The parents became concerned because the left maxillary cuspid erupted in a buccal and mesial position and the right cuspid failed to erupt. The mandibular arch form and tooth alignment was acceptable with the teeth in good relationship to the supporting bone and in good balance with facial musculature. The maxillary teeth were mesial to the mandibular with protrusion of the incisors and lack of sufficient space in the arch for the cuspids to assume their correct alignment.

Plan of treatment: A full complement of teeth could be maintained if the maxillary teeth could be moved posteriorly, increasing arch length sufficiently to provide space for the cuspid without changing the position of the mandibular teeth. Bands were placed on the maxillary first molar with a cervical appliance.

Center models (Figure 7) are right and left views after two years and ten months of cervical appliance treatment at night. The molars and bicuspids have moved distally into correct functioning relationship with their antagonists in the mandible. There was sufficient space for the cuspids which erupted in fair alignment, but there were details to be corrected, particularly of the cuspids and incisors. I suggested placing full appliances to place these teeth in better alignment and functioning relationship. The patient refused to have bands placed on the

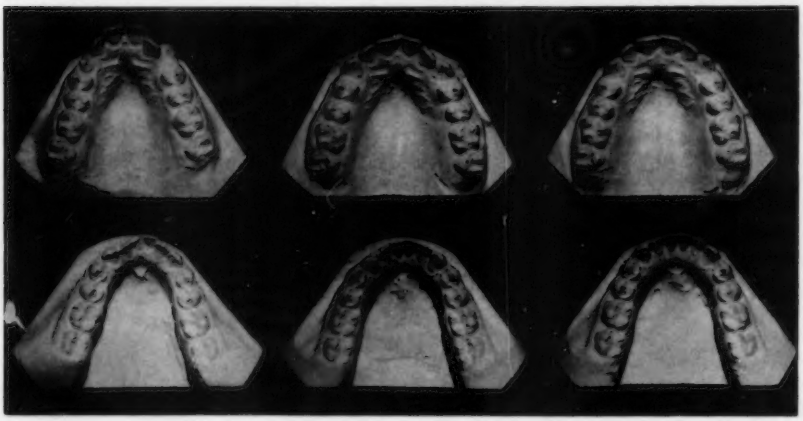

Fig. 8

Fig. 9

anterior teeth but was not satisfied with their alignment. It was impossible to convince her to permit me to place appliances for a short time. The only alternative was a positioner to be worn at night.

Lower models are right and left views after one year of wearing the positioner at night. This case, in my opinion, would have been more successful with only cervical appliance if treatment could have been started in the mixed dentition at about eight years of age.

Figure 8 shows the occlusal views, left before treatment, center after cervical appliance therapy, and right after wearing the positioner for one year.

The before treatment photos are illustrated in Figure 9 above and at the conclusion of treatment below. Her facial balance is acceptable with good functioning occlusion. In my opinion, treatment at an earlier age would have provided better facial balance. She was one of those difficult individu. ls who wanted correction of her malocclusion but refused to have bands on her anterior teeth.

Figure 10 (upper) shows right and left model views of a Class II, Division I malocclusion in a male, seven years of age. The mandibular arch form is good with the teeth in good relationship to supporting structure and in good balance with the musculature. The maxillary teeth are anterior to the mandibular with severe protrusion of the incisors and the alveolar process. The facial musculature is well-developed but with hypotonicity in action.

Our plan of treatment was to inhibit the forward growth of the alveolar process and to move the maxillary teeth distally into correct relationships with their antagonists in the mandible. Bands were placed on the maxillary first molars with a cervical appliance. The teeth were in correct relationship after fourteen months, but the cervical appliance was continued another twenty - two months because of the denture protrusion. It was thought essential for best facial balance and development to inhibit the forward growth of the maxil-

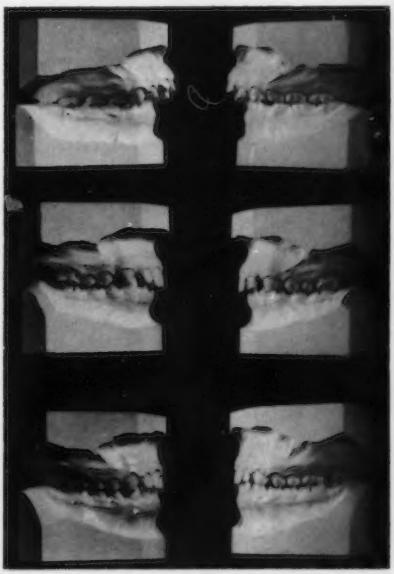

Fig. 10

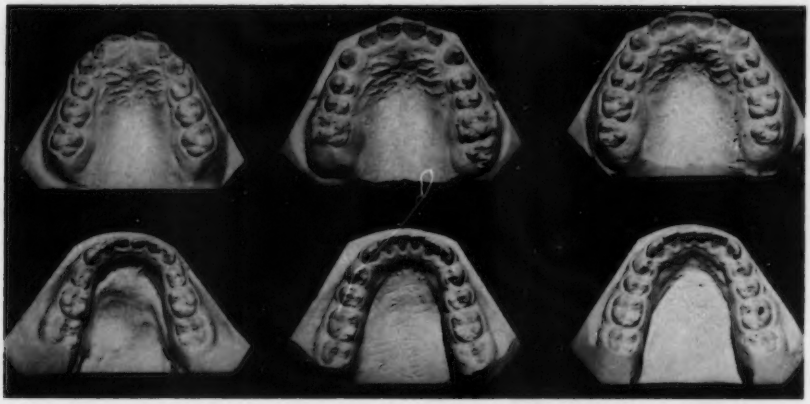

Fig. 11

lary denture as much as possible.

Right and left views of the same case after eruption of all the cuspids and bicuspids are shown in Figure 10 (center). The teeth were in correct mesiodistal relationship with open contacts in the lateral incisor, cuspid and first bicuspid areas of both jaws. In my opinion, there was still a protrusion of the denture with considerable hypotonicity of the musculature. Full edgewise arch appliances were placed on the upper and lower teeth to close contact points and to obtain a better functioning relationship.

Fig. 12

The lower models (Figure 10) are right and left views after twelve months of treatment. The teeth are in good alignment and functioning relationship and have remained the same over the past three years.

Figure 11 illustrates the occlusal views at the start of cervical appliance treatment (left), after eruption of cuspids and bicuspids (middle), and after twelve months of full treatment (right).

In Figure 12 are seen the photographs before treatment and at the end of his second period of treatment. The facial balance may not be the ideal we like and strive to obtain. This is another individual with a different facial pattern, different growth pattern and different musculature. His is the type of case where cervical appliance use is most essential to obtain the best possible in facial balance, functioning relationship and stability of result.

Right and left views of a Class II malocclusion in a male fourteen years of age are illustrated in the upper models of Figure 13. The mandibular arch form and tooth alignment is good with just a slight crowding in the incisal

Fig. 13

area. The maxillary buccal teeth are mesial the width of one cuspid to their antagonists in the mandible. There is a severe crowding and overlapping of the maxillary incisors while the mandibular incisors are functioning against the soft tissue of the palate. The facial musculature is good with the mandibular teeth in favorable relationship to the supporting bone.

It was planned to move the maxillary buccal teeth distally to their correct relationship with the mandibular without disturbing the mesiodistal position of the mandibular teeth. Arch length would be increased sufficiently to place the maxillary incisors and cuspids into good alignment and relationships.

As in the other malocclusions bands were placed on the maxillary first molars with cervical appliance to be worn at night.

Center models of Figure 13 are right and left views after fifteen months of cervical appliance treatment. The mesiobuccal cusps of the maxillary molars occlude in the distal grooves of the mandibular first molars. The maxillary bicuspids and cuspids followed the molars, but left open contacts between these teeth. At this time full edgewise arch appliances were placed on the teeth of both arches with continuation of cervical anchorage appliance on the maxillary first molars.

The lower models of Figure 13 are right and left views after fifteen months of treatment with edgewise arch appliances and cervical anchorage.

The occlusal views of this case are

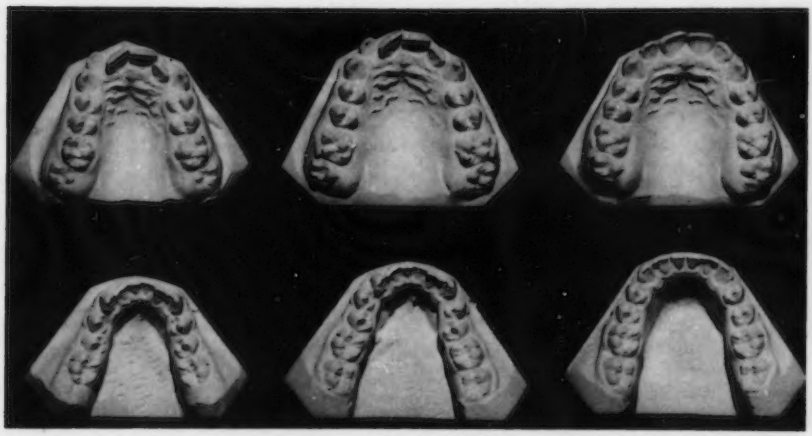

Fig. 14

Fig. 15

in Figure 14, before treatment models are on the left, after cervical anchorage treatment in the center, and after fifteen months of combination on the right.

I believe early treatment at about eight years of age with cervical appliance would have provided better facial development with more satisfactory facial balance than is recorded in Figure 15.

Lateral views of a Class II, Division II malocclusion in a female, eight years of age are shown at the top of Figure 16. The maxillary right primary cuspid, primary first molar and primary second molar had been lost at an early age resulting in a severe mesial drift of the permanent right first molar. It was completely mesial to the mandibular first molar with no occlusal contact. The distobuccal cusp of the left maxillary molar was occluding with the mesiobuccal cusp of the mandibular molar. The mandibular arch form was fair, with mesial tipping of the permanent first molars resulting from failure of eruption of the primary second molars because of ankylosis. The mandibular incisors were contacting the soft tissue of the palate about three-eights of an inch lingual to the maxillary central incisors. Facial musculature was well-developed.

Her lower teeth seemed to be in good relationship to the supporting bone but there was an apparent lack of vertical growth. The mandibular arch length could be made adequate by uprighting the first molars with distal tipping of these teeth. The mandibular teeth would still be in good balance, but could not serve as adequate anchorage for the pull of Class II elastics necessary to move the maxillary teeth distally. The maxillary teeth were mesial to the mandibular with a deficiency of vertical growth in the buccal segments. The upper central incisors appeared to be overerupted with the typical Class II, Division II lingual axial inclination.

Plan of treatment: Use a cervical appliance to move the maxillary first molars distally to their proper positions and inhibit their forward growth together with that of the alveolar process. Place bands on the mandibular first molars with a lingual arch to upright these teeth. Remove the ankylosed mandibular right and left primary molars. When the permanent cuspids and bicuspids erupt, place full edgewise arch appliances to open the bite, correct axial inclination of all teeth and place them in good functioning relationship.

In the center of Figure 16 are the right and left views after twenty-six months of cervical appliance treatment with bands only on the maxillary first molars and a lingual arch in the mandible. The molars are in correct relationship to their antagonists with all the permanent teeth erupted except the mandibular right second bicuspid; this tooth was late in formation with retarded eruption. Increase in vertical height in the molar area would have been desirable, but the cervical appliance failed to stimulate or produce this.

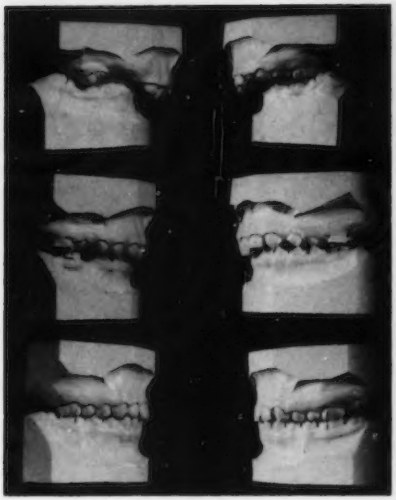

Fig. 16

Full edgewise arch appliances were then placed. Treatment continued for two years with a continuation of cervical appliance on the maxillary first molars. Treatment was prolonged by the delay in eruption of the mandibular right bicuspid.

Lower models of Figure 16 show right and left views at completion of treatment. The patient has a full complement of teeth in correct functioning relationship with good alignment and acceptable facial balance.

Fig. 18

Occlusal views are depicted in Figure 17, left before treatment, middle after a cervical appliance and right after two years of combination treatment.

This was a long period of treatment, but the final result warranted the same. The patient was most cooperative and appreciative which is always rewarding. The vertical dimension of the face has improved (Figure 18). The denture is

Fig. 17

Fig. 19

Fig. 21

in good functioning relationship and in stable balance. Cervical appliance treatment was the key to the success of treatment in this case.

Figure 19 (upper) are right and left views of a Class II, Division I malocclusion in a male, twelve years of age. The mandible appears to be retarded in development with an early loss of the primary molars. The mandibular first molars are tipped mesially inhibiting the eruption of the second bicuspids. The mandibular incisors were functioning on the soft tissue of the palate about three-fourths of an inch lingual to the maxillary incisors. The maxillary teeth were mesial to the mandibular with severe protrusion of the incisors.

Fig. 20

I feel there has been a severe disturbance in mandibular growth with lack of arch length and a discrepancy in maxillary development with the teeth mesial to supporting bone.

Plan of treatment: Start treatment with cervical appliances placing bands on the maxillary first molars to move the maxillary teeth distally and to inhibit the forward growth of the maxillary dental arch and alveolar process. This will permit observation of mandibular growth. When the maxillary buccal teeth are in correct functioning relationship, take complete records and plan final period of treatment.

Right and left views after twenty-two months of cervical appliance treatment with bands on only the maxillary first molars may be seen in Figure 19 (center). The molars are in Class I relationship with eruption of all the permanent teeth including the second molars. Mandibular growth was not favorable and the sacrifice of four bicuspids was necessary to place the teeth in good relationship to supporting bone and in a better balance with facial musculature. Full edgewise arch appliances were placed with continuation of cervical force on the maxillary first molars to keep these teeth from moving forward while closing spaces of extracted first bicuspids. The cervical appliance serves as excellent anchorage in stabilizing molars in treatment of disharmony where bicuspids are extracted, and the aims of treatment demand a distal and lingual movement of the cuspids and incisors.

The lower models of Figure 19 are views showing the result of sixteen months of edgewise arch treatment. These models were made four years after completion of treatment and two and a half years after all retention was removed. The maxillary third molars were starting to erupt. The mandibular third molars were impacted and had been removed. There is about a one millimeter open contact between marillary cuspids and second bicuspids.

On the left of Figure 20 are the occlusal models before treatment; the result of cervical appliance therapy is in the middle and the right views are those two and one-half years after discontinuing retention.

Figure 21 records his face before treatment and after retention.

Summary and Conclusion

These seven cases of Class II malocclusion are a very small sample but sufficient to give an indication of some of the variations each individual presents. The only similarity was the mesial relationship of the maxillary teeth to the mandibular — or the distal relationship of the mandibular to the maxillary. There might be a difference of opinion as to which it was in each case, but the basic plan of treatment remained the same, namely, the moving of the maxillary teeth distally without disturbing the position and balance of the mandibular teeth. The treatment of any malocclusion will be successful and stable if the teeth are placed in a dynamic balance within the limits of the patient's morphologic, physiologic and genetic patterns. The problem is, "What are the limits for each case?" Our treatment plan was based on the assumption that the mandibular teeth were in balance and in correct relationship to the supporting bone and surrounding musculature. The aim of treatment was directed toward moving the maxillary teeth distally into correct functional relationship to their antagonists in the mandible without moving the mandibular teeth mesially.

Cervical anchorage treatment served most efficiently toward this goal. The response in the alignment of all the teeth and in facial balance varied in each case. The time of treatment varied

not always by choice of the operator but by the opportunity afforded.

Studies on time of treatment do not permit any definite rules. The many variables of each case will always remain a challenge to the clinical orthodontist in treatment planning and mechanical therapy. The correct time to institute treatment will reduce the amount of appliance with the minimum disturbance of tissue and provide the best facial balance and stability in each case. We can assume early treatment is a distinct advantage in guiding growth.

Cervical anchorage treatment has proven most successful in my hands in obtaining the best facial balance and stability of occlusion. The force is gentle on the tissue and permits the moving of only those teeth that need to be moved, thereby reducing the stress and irritation on those in correct position. Mandibular arch length and width can be increased in some cases to correct slight rotations and overlapping contacts if these teeth are not used as anchorage for Class II elastics. Clinical evidence and cephalometric findings clearly indicate the mesial movement of mandibular teeth under the force of Class II elastics.

There is sufficient evidence of the distal movement of maxillary teeth by cervical anchorage force. The forward growth of the dental arch and alveolar process is inhibited in many cases. It is essential to continue investigations to determine the extent of the influence of this force on a growing face. Perhaps we can modify our therapy with reduction in treatment time and operator's chair time thereby making it possible to extend our services to many children denied them today.

Zuelke Bldg.

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The Soft Tissue Profile, Growth And Treatment Changes

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Introduction

The improvement of facial esthetics has rapidly become one of the desirable objectives of orthodontic treatment. Despite this, present day concepts of what constitutes a favorable facial appearance are quite controversial in nature and have not been clearly formulated. In many instances evaluations of facial esthetics seem to be singularly influenced by the individual orthodontist's concept of a pleasing face.

At the present time it does not seem possible to devise a "prescription" for differentiating a desirable from an undesirable soft tissue facial profile. Whether such an analysis can be simplified to the degree that it has been done for the skeletal face, so that it may be offered for diagnostic purposes, remains strongly questionable. However, this should not prohibit the presentation of some reference information to guide the thinking and practice of the orthodontist. In his clinical capacity each orthodontist has numerous opportunities to enhance significantly facial appearance, and thus has a need for such reference information. It may be comfortable to think of the soft tissue as a drape over the facial skeleton; however, orthodontists can't relax in the assumption that an analysis of the skeletal profile will correlate directly with an analysis of the soft tissue profile. Therefore, if the orthodontist is to adapt his treatment to modifying facial appearance, it would seem important to know what changes will usually occur within the soft tissue profile as a consequence of growth. After all, it is the soft tissue that primarily determines the facial appearance of any given individual. It should also be stimulating to speculate relative to soft tissue changes which may be expected to occur as a direct consequence of orthodontic therapy and the resulting changes in the underlying hard tissue structures.

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*The author gratefully acknowledges the kindness of Dr. B. Holly Broadbent in making available serial cephalometric films from the files of the Bolton Fund, Western Reserve University.

Changes Incident to Growth

A. The Skeletal Foundation. A consideration of changes in the skeletal profile, incident to growth, could add little to the vast reservoir of information already available to the orthodontist for use in diagnosis and treatment planning. However, it should be realized that a comprehensive knowledge of changes in the skeletal profile is necessary to provide a base line from which soft tissue profile changes can be assessed. Any description of changes in the soft tissue profile alone would not make it possible to specify how much of the total change results from soft tissue alteration and how much results from modification of the underlying skeletal structures.

In the past a good starting point in the interpretation of facial form has been an evaluation of the position of the skeletal chin. The mandible, forming the lower aspect of the face, makes a good skeletal reference structure from which the characteristics of the face

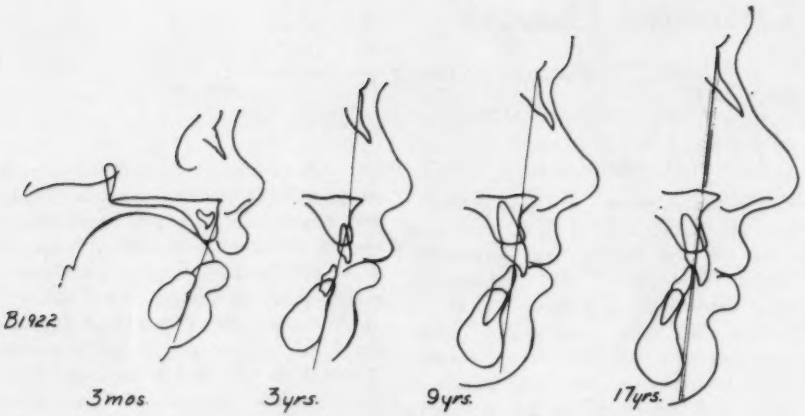

Fig. 1 Tracings of serial cephalometric roentgenograms of a case obtained from the files of the Bolton Study at Western Reserve University. Progressive forward positioning of the chin is evident.

could be formulated. Thus it would seem propitious to briefly consider changes in the position of the skeletal chin incident to growth. On the basis of many studies, [2-8] it can be safely stated that with continuing growth the chin will tend usually to assume a more forward position relative to the forehead and the more superior aspects of the skeletal face (Figure 1). Everyone is familiar with the fairly common facial appearance of most babies at the time of birth. Their chins are usually quite receded while there appears to be a more or less pronounced protrusion of the maxillary aspect of the face. With growth there usually is a marked transformation of the face. The general tendency seems to be for the mandible to grow from the more retruded to a less retruded position. This will usually be true regardless of the individual facial type at the onset and completion of growth.

Of course, differences in the degree of change in the position of the skeletal chin must be considered on the basis of sex as well as individual variation. For instance, it can be anticipated that over the years males will usually show a greater increase in mandibular prognathism. It should also be remembered that in males a significant proportion of the total changes occurring in lower face prognathism will be expressed during and after puberty. In contrast to this, females will usually show a proportionately smaller degree of mandibular development after puberty. Although, in the last analysis, there may be little difference in mandibular prognathism when the female adult is compared with the male adult, the differential in the timing of mandibular growth may be important when treatment procedures are being considered.

Without question the facial appearance of any individual is not only dependent on mandibular position but, in addition, on the anteroposterior relationship of the maxillary jaw to the mandible or vice versa. Briefly, and at the risk of being too elementary, the following seem to be the generally accepted changes in the characteristics of the skeletal profile with growth. It can be generalized that during the growth span from childhood to adulthood the

Fig. 2 Tracings of serial cephalometric roentgenograms of a case obtained from the files of the Bolton Study at Western Reserve University. Progressive decrease in skeletal convexity can be noted.

maxillary jaw will tend to become less and less protrusive relative to the rest of the skeletal profile. That is, there is a definite tendency for the skeletal profile to become less convex with growth (Figure 2).

This finding that the maxillary jaw tends to become less prominent relative to the rest of the skeletal profile indicates some disproportionality in facial growth. The maxilla tends to be positioned in a forward direction much more slowly than does the mandible, resulting in a decrease in the convexity of the facial profile. This difference in the degree of jaw growth in an anterior direction will determine the final facial type when growth has been completed.

Some differences must be anticipated in facial profile changes on the basis of sex. As has been mentioned, female subjects will usually not become as prognathic in the mandibular region as will male subjects. Therefore, females will usually not attain the same degree of straightness in the skeletal profile when compared with males.

Despite these changes in jaw relationships with growth, comparable changes have *not* been noted at the approximate levels of the bases of the alveolar processes. It has been stated that after approximately seven to nine years of age, point B, or the supposed level of delineation between the mandibular alveolar process and skeletal bone, does not exhibit much forward change relative to point A[3,9] the comparable landmark in the maxillary region. Thus it can be generalized that the alveolar processes can be expected to exhibit some stability in their anteroposterior relationship to each other after nine years of age while their supporting skeletal bases will continue to grow and change in anteroposterior relationship.

B. The Soft Tissue Profile

Prior to a discussion of changes in the position of the dentition this seems the opportune time to present some of the more recent information related to growth changes in the soft tissue structures which cover the skeletal profile. Wherever possible, changing characteristics of the soft tissue profile will be

defined as they relate to the underlying skeletal profile.

It has been demonstrated that the position of the integumental chin is very closely related to the position of the skeletal chin[10]. That is, as the skeletal chin assumes a more forward relationship to the cranium with growth, so will the soft tissue chin (Figure 3). In addition, the amount of increase in the prominence of the soft tissue chin will closely correlate with the degree of change in the prominence of the skeletal chin. Therefore, when considering basic facial form and mandibular position, it can be anticipated that the soft tissue profile of most individuals will usually tend to become less retrognathic with progressive growth and development. Of course, the same fundamental differences, relative to age and sex, can be noted when comparing integumental and skeletal mandibular prognathism.

Although, when considering mandibular prominence, the soft tissue chin has been found to follow closely the skeletal chin, the same close correlation could not be demonstrated when the convexity of the soft tissue profile was studied[10]. Soft tissue landmarks, which are closely analogous to the bony landmarks used for measuring the convexity of the skeletal profile, were established. Analysis of the measurements revealed that the soft tissue structures overlying these skeletal landmarks did not show the same pattern of change as that observed for the bony profile. Whereas the average hard tissue profile definitely tends to become straighter with age, the analogous soft tissue profile tends to remain comparatively stable in its convexity. On the average, although showing a very slight tendency to straighten with age, little change in the angular degree of soft tissue convexity was found to take place after approximately six years of age.

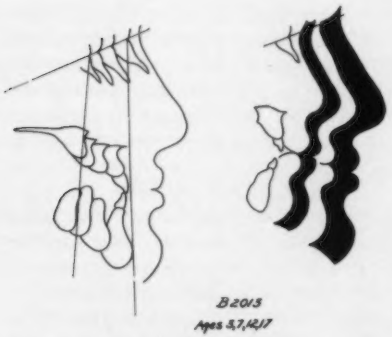

Fig. 3 Serial tracings depicting the forward positioning of the soft tissue chin with the forward positioning of the skeletal chin.

The fact that the soft tissue covering does not follow the apparent tendency of the bony profile to straighten with age seems of considerable importance. For one thing it indicates that there may be a growth differential in the thickness of the soft tissue covering the various aspects of the underlying hard tissue. Obviously, the configuration of the midsagittal soft tissue profile can be affected by differences in the thickness of the soft tissue overlying skeletal structures. To a degree this possibility has been substantiated by the finding that there is a comparatively greater increase in the thickness of the soft tissue covering the maxillary jaw than in the soft tissue covering the mandibular symphysis and the forehead area[10]. Thus, considering the soft tissue covering alone, this would tend to swing the soft tissue profile toward the direction of a more convex rather than a less convex facial profile. The difference in the forward growth of the bony chin carrying its overlying soft tissue and the comparatively reduced forward growth of the anterior part of the bony maxillary jaw seems to be partially compensated for by this differential in the increase in

soft tissue thickness covering the upper face.

It is also credible that the upper lip, by virtue of its attachment to the nose, may be affected in its thickness and position by growth tendencies of the nose itself. Therefore, it would seem important to consider the growth of the nose and its influence on the soft tissue profile.

When the nose is included in the profile appraisal, the soft tissue profile can be expected to increase in convexity with progressive growth and development. This can be expected since it has been shown that the nose will grow in a forward direction to a proportionately greater degree than will the other soft tissues of the facial profile. That is, with continuing growth, the nose will increase in its projection relative to the total facial profile.

The human nose will continue to grow in a downward and forward direction at least until early adulthood (Figure 4). Surprisingly enough, the external nose seems to undergo an appreciable amount of growth during the later stages of development as well as during the earlier stages. There does not seem to be an appreciable decrease in the rate of nasal growth as is typical of the growth pattern established for the skeletal structures of the upper face which form the nasal cavity. There appears to be an average yearly increase of one to one and a third millimeters in the overall length of the external nose. The degree of increase can be expected to be approximately the same for male and female subjects.

In most instances the profile of the external nose will tend to maintain the same general contour with growth except for a few modifications. The nose will usually become more inclined in a forward direction and the tip of the nose, formed by a continuation of the bridge of the nose and the columella,

Fig. 4 Serial tracings, superimposed on the sella-nasion plane, registering on nasion, depicting the downward and forward growth of the nose at ages five, eleven, and eighteen years.

will become more acute during the later stages of development[11]. In many males a growth spurt for the nose can be found to occur somewhere between ten to sixteen years of age. Subjects who do show this growth spurt will also show some difference in the contour of the nose with a forward positioning of the nasal bone and concomitant elevation of the bridge of the nose.

While studying growth of the nose, it also became obvious that there is a difference in the amount of growth of the horizontal and the vertical dimensions of the nose. In most instances the nose tends to grow longer vertically to a greater extent than it does horizontally. It is in the anteroposterior or the horizontal growth of the nose that a sex difference can be noted. Females will usually show a greater increase in the depth of the nose than will males. In fact from nine to fifteen years of age, the nose tip will usually increase on the average of one millimeter per year anterior to the facial plane [11]. Thus the sum total of the effect of the growth of the nose on the configuration of the soft tissue profile is to make the facial profile more convex with age. This, of course, is related to the increase in

nasal prominence relative to the facial profile.

In the last analysis it must be anticipated that not all of the soft tissue facial profile will manifest the characteristics of the underlying skeletal profile. The apparent incongruity between the convexity of the skeletal and the soft tissue profiles indicates that the soft tissue of the upper face is not directly related to the hard tissue of the upper face. In contrast to this the position of the soft tissue overlying the mandibular symphysis seems to be directly dependent on the position of the chin.

Integration of information which is to be useful to the orthodontist must, of necessity, also evaluate the soft tissues forming the profile of the mouth. The lips are closely related to the dentition and being partially composed of muscle have a functional influence on the underlying dental structures.

The growth of the lips was found to follow the general growth curve for muscle and other connective tissue within the body[12]. The upper and lower lips gradually increase in length; the upper lip was found to grow away from the level of the palate while the lower lip was also growing away from the chin. A progressive increase in lip length was found to take place until approximately fifteen years or age. After this age growth in length seemed to slow down markedly. With this increase in lip length there was also an increase in thickness, especially in the vermillion region of the upper lip. In both sexes the lips attained a proportionately greater thickness in the vermillion regions than in the regions overlying skeletal points A and B. In fact, as the growth of the lips was studied, it was observed that the upper lip increased in thickness at the vermillion level approximately the same amount as it increased in length.

It is interesting that, despite this progressive increase in length, both lips tended to show a fairly constant vertical relationship to their respective underlying alveolar processes. After approximately nine years of age, that is, after the approximate time of the full eruption of the central incisors, there is little, if any, increase in the vertical distance between the crest of the alveolar process and the vermillion border of the lip at the level of lip approximation. This permits the hypothesis that, after this age level, vertical growth of the alveolar processes and vertical growth of the lips tend to keep pace with each other. The question also arises as to whether the lips maintain an equally constant relationship to the incisal edges of the anterior teeth. Here also, a fairly close relationship was observed to exist. After the time of the complete eruption of the central incisors, the tips of the lips have been found to be closely related to their incisal edges. Specifically, after about nine years of age, the tip of the upper lip was found to cover usually sixty-one to sixty-seven per cent of the maxillary central incisor crown. The remainder of this tooth, of course, is usually covered by the vermillion aspect of the lower lip.

The anteroposterior posture of the vermillion aspect of the lips was also found to be closely related to their supporting hard tissue structures, that is, the teeth and alveolar processes. When serial tracings of the same individual have been superimposed, it has been observed that in a majority of the cases there is an uprighting of the mandibular alveolar process and the central incisor (Figure 5). The mandibular alveolar process was seen to become more retruded relative to its supporting skeletal bone, that is, the chin. The maxillary dentition and alveolar process were also observed to become less protrusive relative to the facial plane of the skele-

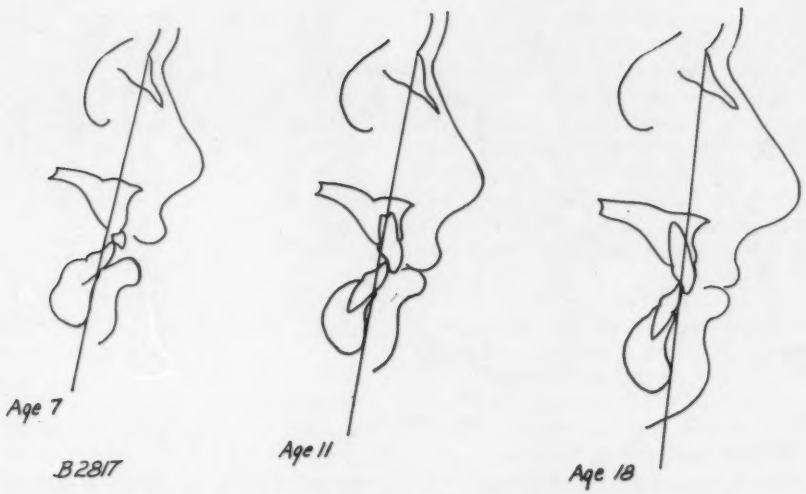

Fig. 5 Tracings of cephalometric headplates of the same subject illustrating the uprighting of the mandibular central incisor relative to the facial plane.

tal profile. The uprighting and retrusion of the dento-alveolar structures were found to take place during the times of increase in mandibular prognathism and decrease in the convexity of the bony profile. As an interesting side note, it was noticed that whereas the mandibular central incisor tended to become more upright and retruded relative to its skeletal foundation, it exhibited some degree of constancy in its angular position relative to the profile of the skeletal jaws. The angle formed by the long axis of the mandibular deciduous and/or permanent central incisor and a line connecting point A with pogonion was measured in thirty cases with longitudinal cephalometric records. On an average this angle increased until nine years of age; that is, this tooth tended to become progressively more procumbent relative to the AP plane. From nine to eighteen years of age, the average angular relationship between the lower incisor and this plane tended to become more stable. Of the thirty cases, twelve cases showed no change in the angular relation of the lower incisor to the AP plane during this time interval; twelve cases showed an increase in this angle or a greater procumbency of the lower incisor, while six cases exhibited the tendency for this angular relationship to decrease. Of the latter two groups which showed change, in the majority of the cases it was found to be of the small magnitude of four to five degrees during this nine year interval.

If the mandibular alveolar process and the mandibular incisor are supposedly uprighting relative to the chin, the question may arise as to why this tooth maintains a reasonably stable relationship to the AP plane. It has been pointed out that with growth pogonion is going forward more rapidly than point A resulting in a straightening of the skeletal profile. The very fact that the mandibular incisor is becoming more upright with growth permits it to maintain a somewhat constant angular relationship to the jaw profile.

Of particular interest to orthodon-

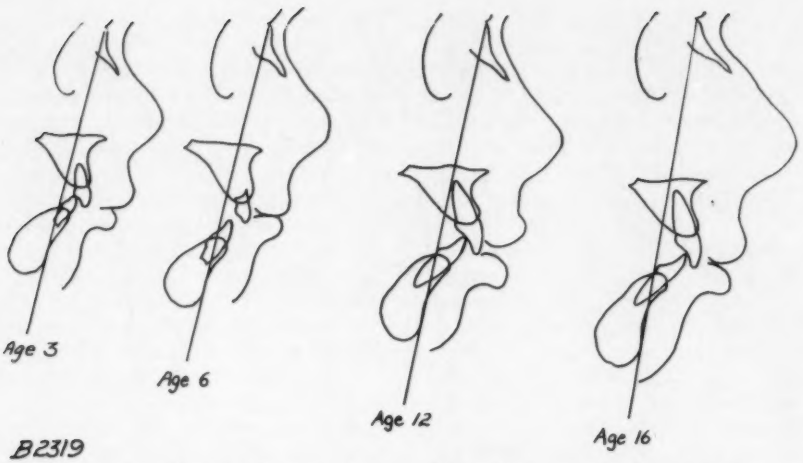

Fig. 6 Superimpositioning of tracings of the same individual on the facial plane to indicate progressive protrusiveness of the central incisors and the lips.

tists is the observation that the vermillion aspect of the lips tended to maintain a close postural relationship to their supporting structures. When the denture and alveolar process became more upright relative to the facial profile, the lips were found to become more retruded relative to the facial profile. In a few instances where the dentures and alveolar processes became more protrusive relative to the facial plane, the lips also showed the same directional modification and were protrusive within the facial profile (Figure 6). Thus it may be generally stated that the posture of the lips is strongly dependent on the position of the underlying dento-alveolar complex.

In summary then, it can be re-emphasized that the position of the soft tissues covering the upper face, exclusive of the dental area, does not closely reflect the position of the hard structures of the same area. In contrast to this, the position of the soft tissues covering the lower jaw as well as the mandibular and maxillary dento-alveolar areas is strongly dependent on the position of these hard tissue structures. This strong interrelationship between the lips and the dental structures is obviously important to the orthodontist. He is attempting directly to regulate the position of at least one of these structures.

This brings us to the point of attempting to discuss some of the clinical implications of this information. How can we utilize this information to help us in our diagnosis and to augment our treatment procedures? The wisdom and skill of the orthodontist is most usually directed toward improving his patient's masticatory function and facial esthetics. There has been some controversial discussion as to whether improvement of facial esthetics should receive any emphasis whatsoever as a part of orthodontic diagnosis and treatment planning. Such discussions may have some justification in the sense that direct correlations between functional occlusal relationships and dento-facial esthetics have not been clearly established. However, whether this correlation does or does not exist, it must

Fig. 7 Superimpositions of tracings of the same individual illustrating changes in the soft tissues of the face with progressive growth.

be recognized that the improvement of facial aesthetics has been considered by many capable individuals to be an important objective of orthodontic treatment[13-18]. Therefore, an intelligent anticipation of soft tissue modifications which may occur incident to normal growth and those which may occur incident to treatment can only be helpful in achieving one of the aforementioned objectives.

One cannot question that improvement in the configuration of the facial profile can occur with or without the help of orthodontic treatment. Growth itself, with no orthodontic procedures, can bring about changes in the contour of the soft tissues of the face (Figure 7). For one thing, growth of the mandible will cause the skeletal chin to move forward — which in turn will carry the soft tissue chin forward to a comparable degree. If adequate growth occurs, the inferior aspect of the face could assume a good postural relationship, one which may be well positioned for a pleasing facial profile. Without it the foundation for a good superstructure may be lost.

Growth of the nose will usually take place whether or not orthodontic treatment is initiated in any given individual. Normally it must be anticipated that the growth of the nose can improve the contour of the soft tissue profile. During the later growth stages, as has been mentioned, the nose and soft tissue chin are observed to move forward relative to the lips.

In fact, the forward positioning of the nose occurs to a greater extent than does the forward positioning of the chin. The rapid and disproportionate forward positioning of the nose and chin causes the lips to seem to be receding within the facial profile. One can readily see that in certain facial types this would be desirable. This may be a feasible explanation for some of the cases reported to have protrusive lips at a young age and said to show an improvement in the position of the lips by adulthood. This has reputedly occurred with little or no orthodontic treatment, or treatment without extraction procedures, when such would presently be indicated.

It should also be noted that in some cases with inherently poor nasal characteristics, growth of the nose may serve to the disadvantage of both the patient and the orthodontist. For example, an individual with a very prominent nose will probably continue to maintain a prominent nose. With growth, this type of face may become even more convex (Figure 8). In such instances some procumbency of the lips and denture may be desirable. Anything which would serve to retract excessively the lips may be strongly undesirable since it may only result in exaggerating an already prominent nose. On the other hand, in an individual with an inherently small nose, it may be desirable to institute procedures which will cause the lips to retract (Figure 9). In this instance retraction of the lips and continued facial growth may dramatically improve facial appearance. These simple examples are projected solely for the purpose of demonstrating that a knowledge of the growth tendencies of the soft tissues as

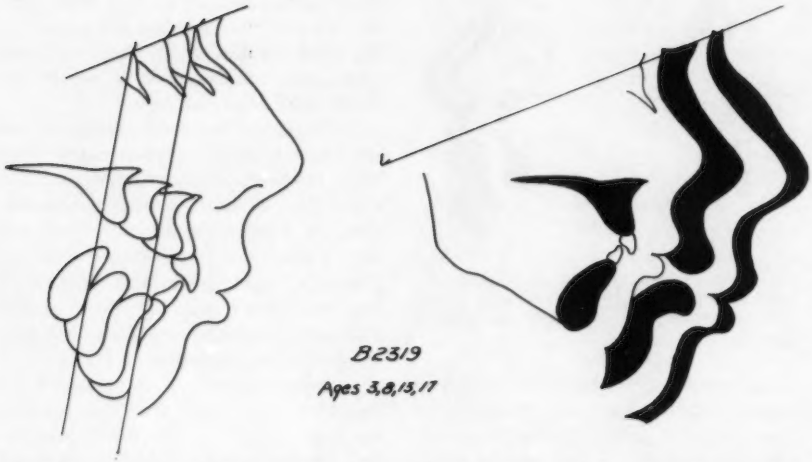

Fig. 8 Superimposed tracings revealing increase in soft tissue profile convexity, somewhat correlated with nasal prominence.

well as the underlying hard tissues may function to guide treatment planning. Any evaluation of the dentition and the skeletal structures of the face must be tempered with an evaluation of the size configuration, relative position and growth potential of the soft tissues of the nose, lips and chin.

Fig. 9 Tracing of a young individual with an inherently small nose and concomitant protrusive dentures and lips.

It must be emphasized that changes in the basic position of the soft tissue nose and the soft tissue chin occur primarily as a function of growth and there is little that an orthodontist can do to alter them. Within reason, he could possibly exert some control over only one of these structures, that is the position of the soft tissue chin. This can be accomplished only if the mandible is, or needs to be, repositioned during treatment, or if orthodontic appliances can be effectively used to stimulate or to restrict the growth of the skeletal mandible. To date, the potential for effectively controlling the growth of the mandible with appliance therapy does not seem exceptionally good. To my mind any effect that the orthodontist can presently exert would be relatively small and, in most cases, quite inadequate.

The question then arises as to what tissue changes can be expected as a consequent of orthodontic treatment.

Since the lips are closely related to underlying structures, it can reasonably be assumed that lip contour can be modified while changing dento-alveolar position. The mouth profile is important to the appearance of the total soft tissue profile. Since the mouth profile can be modified, changes brought about by appliance therapy can affect the soft tissue profile. It is true that the lips themselves will fall back in reference to the soft tissue profile with growth. However, in so doing the lips have been found to maintain the same approximate relationship to each other, much as the skeletal points A and B maintain a proportionate relationship with age. Thus, while the lips may change relative to the profile, there is little change that we can usually hope for in one lip as it relates to the other lip, that is without orthodontic treatment. If normal growth changes will not be adequate for the desired changes, then it may be necessary to resort to orthodontic treatment to attain a favorable lip profile. Whereas growth does not usually alter the relationship of skeletal points A and B, orthodontic procedures reputedly can alter their spatial relationships as well as the position of teeth. With change in teeth and alveolar position come changes in lip position and contour. Indeed, a reliance upon the interrelationship between dento-alveolar and soft tissue contours of the mouth can constitute many times the rationale for orthodontic treatment to improve facial esthetics.

It is not my intention to argue the relative merits of the upper or lower incisor as they relate to changes in the soft tissue profile. Suffice it to say that the most dramatic changes in facial appearance seem to be correlated with cases exhibiting lip protrusions whether it be one or both lips. If we are discussing facial changes, then the instances where a definite retrusion of maxillary incisors has taken place will show considerable amount of change in lip contour and facial esthetics. This is especially true since the lower lip which normally covers the incisal third of the maxillary incisors is also greatly affected by the position of these teeth. It would be foolhardy to surmise that it is only with the correction of the position of the maxillary incisor teeth that dramatic results are elicited. In effect, equally large changes may be noted where the mandibular incisors have to be repositioned over great distances. It seems to me that it can be concisely stated that soft tissue changes incident to treatment will center around the lips, whereas soft tissue changes incident to growth will encompass a greater aspect of the soft tissue profile — the nose and chin as well as the lips. The sum total of both growth and treatment will determine the final facial configuration of any given individual. However, with the lips forming a very important part of the face, modifications in this area can have a dramatic influence on facial appearance.

Case Presentations

This seems a good time to evaluate some of these concepts within the scope of a few treated cases. Because lip protrusions have been stressed, to a degree, several cases where a measurable change in incisor position has occurred as a result of treatment were selected for presentation. It was felt that these cases represented some diversity in changes that were observed to take place in the soft tissue profile. In addition, all of the cases have something in common in that each presented a Class II molar relationship prior to orthodontic treatment. The cephalometric tracings will be stressed since they reveal clearly the changes in the soft tissue profile.

Fig. 10

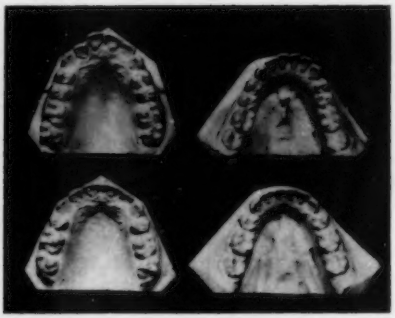

Fig. 11

Case 1 (Figures 10, 11 and 12) This is a case in which little growth was anticipated since this young lady was approaching late adolescence. Analysis of her profile and other characteristics of the case indicated that the extraction of four bicuspids would be advisable. The basic skeletal pattern was not good in that there was a discrepancy in the anteroposterior relationship of the denture bases, in addition to the discrepancies located within the denture itself. After approximately two years of treatment the case was considered ready for retention with an adequate result.

The "before" and "after" tracings were superimposed on the basion-nasion plane, registering on nasion, and the following changes were noted. The analysis of the cephalometric films revealed little growth of the facial skeleton during the two year period. There was a slight increase in the vertical height of the face with some vertical growth of the mandible. Anteroposteriorly, there was little change in the position of the mandibular incisor, while the maxillary incisors were re-

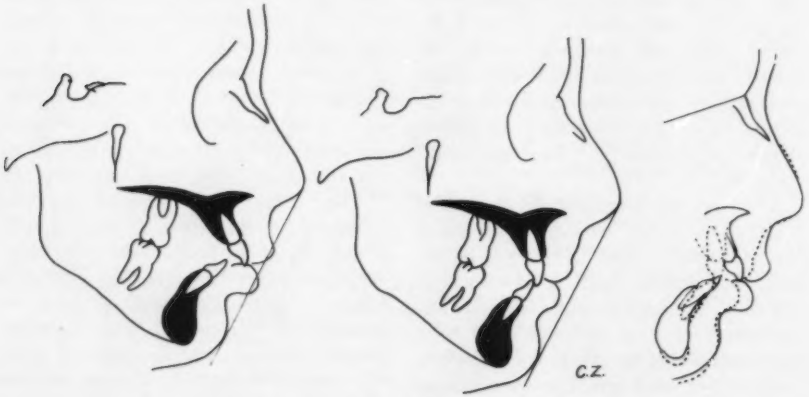

Fig. 12

Fig. 13

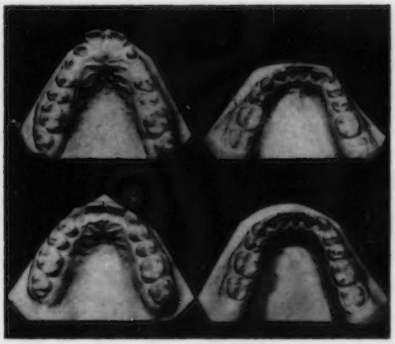

Fig. 14

tracted to a considerable degree. Marked improvement was noted in the soft tissue; this was true in spite of limited growth of the skeletal and soft tissue profiles. No appreciable growth of the nose was noted and the soft tissue chin was observed to follow the skeletal chin. It seems evident that the retraction of the upper incisors was followed by a retrusion of the upper and lower lips. The reduction in the prominence of both lips seems to account for the marked improvement in the soft tissue facial profile.

Case 2 (Figures 13, 14 and 15) This case was obviously a severe protrusion of the maxillary denture. The face of this fourteen year old girl was found to be retrognathic with a pronounced convexity to the configuration of the facial profile. A more concise appraisal revealed considerable discrepancy in the relationship of the denture bases, that is the A-B relationship as well as considerable steepness to the lower border of the mandible. It was further determined that while the maxillary den-

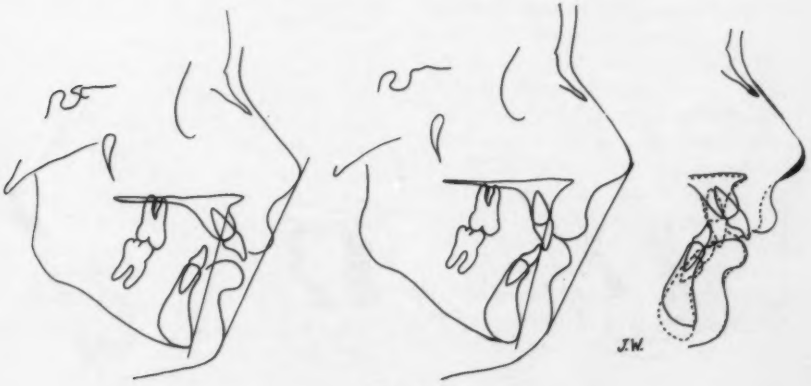

Fig. 15

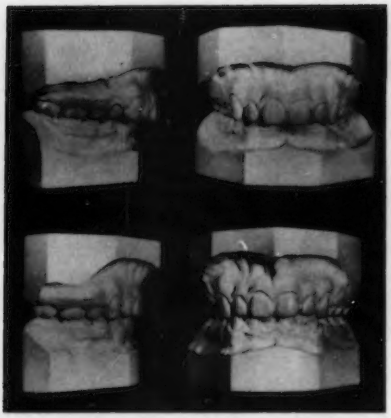

Fig. 16

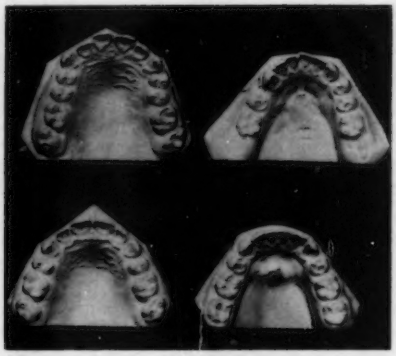

Fig. 17

ture was protruded, there was also a retrusion of the mandibular denture on its base. A reduction in the maxillary dentition seemed indicated. Since the maxillary lateral incisors were congenitally malformed and severely reduced in size, these teeth rather than bicuspids were extracted.

The permanent cuspids were moved into the positions of the extracted laterals and the case was treated within an eighteen month period. A comparison of the cephalometric tracings shows that some growth had taken place during the treatment period. The chin seemed to grow almost directly downward with no forward growth, relative to the profile. As a consequence, the soft tissue chin, following the skeletal chin, did not assume a more forward position. A little forward growth of the soft tissue nose was observed; this seemed to aid in the improvement of the facial profile. Once again, a marked reduction in the prominence of the upper lip served to improve dramatically the facial profile. Considerable retraction of the maxillary incisors and concomitant small advancement of the lower incisors is evident. Whereas the lower lip does not seem to be forward to its previous position, the upper lip has moved back to a considerable de-

Fig. 18

gree. Although more growth was evident in this case, in comparison to the previous case, the improvement in the soft tissue profile in both cases seems to be closely correlated to change in lip position.

Case 3 (Figures 16, 17 and 18) This twelve year old boy presented maxillary and mandibular jaws that were well formed though poorly related to each other. An excessive overbite was evident with some loss in the vertical dimension of the lower face. In this case it seemed advisable to restrict extractions to the maxillary jaw. However, an impaction of the left mandibular first bicuspid caused a decision to extract in the lower arch as well. In this case adequate growth of the mandible was anticipated and hoped for.

As can be seen from the cephalometric tracings, considerable growth did take place during the treatment period. The mandible did grow vertically and forward, relative to the forehead. In so doing the soft tissue chin progressed in the same direction and to a comparable extent. In this individual, growth of the nose occurred to a notable extent progressing in a downward and forward direction relative to the forehead. The forward growth of the nose and the chin coupled with the vertical growth of the face served to appreciably improve facial appearance. The contour of the lips was greatly improved with the retraction of the upper incisors. However, it must be noted that the retraction of the upper lip was not as great as observed in the previous cases. In the last analysis it must be said that growth was most instrumental in improving the soft tissue profile. Some recontouring of the lips and improvement in vertical dimension subsequent to orthodontic correction also helped to improve facial esthetics.

Case 4 (Figures 19, 20 and 21) This case, that of a seventeen year old boy, was characterized by an extremely deep overbite and maxillary buccal occlusion in the bicuspid regions. The patient exhibited some distal repositioning of the mandible when teeth were brought into complete occlusion. This case was treated without extractions. Attempts were made to increase orthodontically the vertical dimension of the lower face to help improve facial esthetics.

The tracings reveal that there was some improvement of the soft tissue profile although not as much as hoped for. The mandible was repositioned in a more forward relationship to the maxillary jaw. This repositioning, plus some mandibular growth, accounted for the forward repositioning of the chin and the lower lip. A small amount of nose growth also took place during this interval. The anterior teeth were tipped forward in both the maxillary and mandibular regions; this also served to bring both lips farther forward. This combination of events certainly improved the soft tissue profile, although facial esthetics could still be improved. Unfortunately, the treatment procedures applied were not able to increase the vertical dimension between the jaws. If success had been attained relative to apparent requirements in vertical dimension, it is felt that the esthetic results would have been considerably better in this patient. Correction of the deep overbite occurred as a result of considerable depression of the lower incisors. This case was presented to show that increased protrusion of the lips can be quite beneficial to facial esthetics where it is indicated. It also emphasizes the repositioning of the soft tissue chin with repositioning, as well as with growth, of the skeletal mandible.

Case 5 (Figures 22, 23 and 24) This patient, a ten year old boy, was ob-

Fig. 19

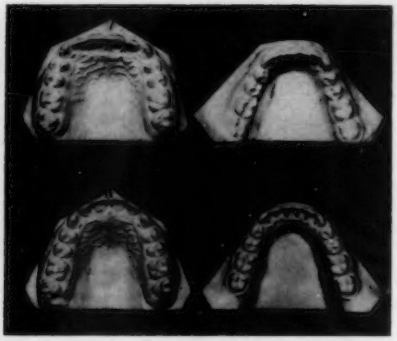

Fig. 20

served to have a pronounced discrepancy in the anteroposterior relationship of the anterior teeth. The maxillary incisors, although in good axial inclination, were protruded while the mandibular incisors were severely retruded and excessively inclined lingually. The upper arch seemed adequately formed while the lower had mandibular cuspids blocked out of the arch.

The youngster was noted to have a pronounced mentalis habit which seemed to account for the severe retrusion of the mandibular incisors. After initial guiding treatment which included a headcap and a lip bumper, the case was subjected to full treatment and completed. The resulting soft tissue profile seemed quite acceptable and markedly improved in comparison with its configuration prior to treatment. In this case a considerable amount of growth expressed itself during the treatment period.

Superimposition on nasion revealed growth and treatment changes with the profile area. Growth of the nose was pronounced as the nose tip progressed in a downward and forward direction. There was a small amount of forward positioning of the soft tissue chin. How-

Fig. 21

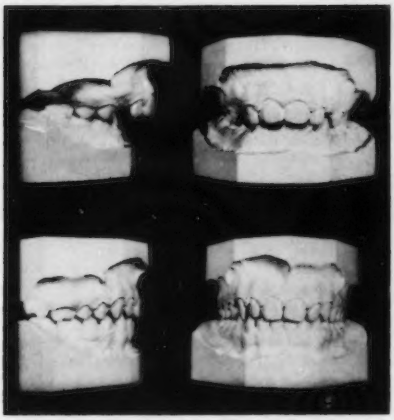

Fig. 22

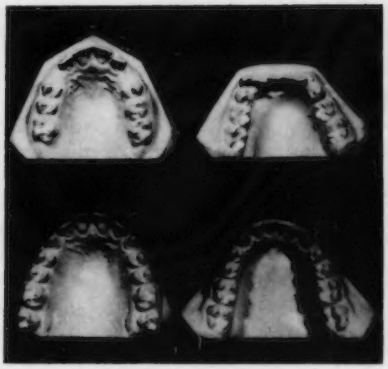

Fig. 23

ever, increase in the vertical dimension of the face was pronounced and consequently there was much change in the vertical position of the soft tissue chin. There was a slight posterior positioning of the upper lip which seems to go hand in hand with the posterior positioning of the upper incisors. In this case, as in the previous, there was a pronounced forward positioning of the lower lip. However in contrast to the other case, this forward positioning of the lower lip was not correlated with any change in chin position but with considerable forward repositioning of the mandibular incisors. The greatest amount of improvement in the 'mouth profile' of this case seems correlated with forward movement of the lower lip.

When tracings are superimposed on more posterior structures, it is obvious that considerable growth of the mandible has taken place with the skeletal chin progressing downward and forward. Nasion has moved upward and forward while point A of the maxilla seemed to progress in a downward and

Fig. 24

slightly backward direction. It is felt that orthodontic therapy had restricted the growth of the maxilla.

Summary

In summary, it would seem wise to emphasize that growth changes within the soft tissue profile will be expressed in the areas of the nose, the chin and the lips. The soft tissue changes that we can anticipate, incident to treatment, will center around the lips, primarily in the vermillion area. Lip posture was found to be correlated closely with the posture of underlying dental and alveolar structures. This is important to the orthodontist since he is capable of modifying, to a degree, the position of teeth and alveolar structures.

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Highlights In Recent Foreign Literature

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INTRODUCTION

I have been asked to present the "highlights" of the foreign literature during the past few years. This has left me pondering as to what constitutes a "highlight". Should it be a momentous accomplished achievement, of which there are few, or should it hold the potential for greatness and thus provide a stimulus for young investigators in this country? I have gathered both.

The fascinating field of orthodontics transcends so many disciplines of scientific investigation that it would be impossible to present them all. Thus this review will be limited, perhaps to those "highlights" which I believe are important. Both fundamental and applied research in the field of orthodontics have been grouped since there should be no dichotomy in our thinking. Similarly I have made no geographical barriers. Although certain areas of the world have produced a large amount of original research, isolated workers in the smaller countries have contributed in no small measure to our total knowledge.

The United States orthodontic journals are to be commended on their abstracting and reprinting of foreign publications. In most instances there may be a time lag of a year or two, but the major advances in the foreign field are well represented. Wherever possible I have omitted articles which have been published overseas and reprinted in detail in our own periodicals. Conversely I have eliminated articles written in the United States and published in the European literature.

This paper has four main divisions. The first is the problem of craniofacial development, the second orofacial musculature, a third the general field of cephalometrics and fourth, researches having a direct bearing on treatment.

CRANIOFACIAL DEVELOPMENT

In an imposing array of papers J.H. Scott has presented a theory of facial growth which differs from that generally accepted in North America. Largely on the basis of comparative anatomy and embryology, Scott has offered the suggestion that the vomer and the median nasal cartilage are the pacemakers in the development of the middle face. The thesis is that the median nasal septum is a projection of the chondrocranium into the facial area and, as the cartilage grows, it carries the premaxilla and maxilla downward and forward. This mechanism is assumed to be responsible for snouting in animals which have a separate premaxilla, that is, growth separating maxilla from premaxilla. In the human the early fusion of the premaxillary-maxillary suture is responsible for carrying the facial mask forward until the time of eruption of the permanent molars. After this time surface growth is allegedly responsible for most of the facial growth. Recently Scott has suggested that it may be possible that sutural growth continues after the first decade of life.

Naturally this places an increasing emphasis on the role of the facial sutures. In Scott's theory these sutures would be under a certain amount of tension. Thus it was of great interest to

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see a paper published by Pritchard which investigated the role of the facial sutures. Pritchard's paper dealt with the histology of the growing facial and cranial sutures and tended to confirm Scott's belief that the sutures were not under pressure. The material was embryologic and comparative. Although there was a slight difference in the formation between the cranial and facial sutures, it was concluded that, "sutures form a strong band of union between adjacent bones while permitting slight movements, and at the same time allowance was made for marginal expansion of the bones during the growing period".

On the other side of the globe, Murphy in Australia was investigating the growth and function of the mandible. In so far as mandibular growth was concerned, Murphy employed an elaborate method of superposing tracings of mandibles and showed how the basic form or core of the mandible, originally straight, became progressively bent with age. This implied directional growth at the head of the condyle.

That such directional growth was likely and did occur was shown by Bjork. In a novel way Bjork placed small vitallium implants in the alveolar and basilar portions of the dental arches in a limited number of humans. In effect this was a series of metallic implants which were then followed by serial radiographs. Despite the loss of many of the implants through modelling resorption, definite trends in facial growth and directions of eruption of the dentition were shown. By superposing the radiographs of the metallic implants a directional growth of the condyle was shown. Growth may be in a vertical or horizontal direction. Although this paper was a preliminary report it aroused considerable speculation as to the amounts and directions of facial growth. In addition to implants in humans Bjork is presently carrying out implant techniques in the Macaca rhesus.

Together with the facial area considerable attention has been directed to the growth of the cranial base. In this regard there have been two significant contributions. Baume, in an endeavor to understand the changes which are liable to occur at sella turcica, performed a histological study of the cranial base of the Macaca rhesus. He came to certain interesting conclusions: first, that the synchondroses act as epiphyseal cartilages, but differ in that bone is being deposited on both sides of the cartilage; second, that growth at the synchondroses is governed by genetic and endocrine factors; lastly, that there is continuous bone transformation at sella turcica and the clinoid processes, the implication being that there could be considerable movement occurring at sella point.

In an investigation of the growth of the cranial base of the Macaca rhesus, Lager, (working in Bjork's laboratory) employed metallic implants in the cranial base on each side of the sphenoccipital synchondrosis. He concurred with Baume in the histology of the cranial base and, in addition, presented the idea that there existed a differential in growth along the spheno-occipital synchondrosis so that there was a greater amount of growth on the more inferior area. In this fashion he explained the flexion of the cranial base as occurring in growth.

Continuing investigations from the Vasteras growth study, Bjork has reported several cephalometric studies. Together with Jensen and Palling an interesting paper on mandibular growth and third molar impaction concluded that impaction may depend upon three factors: 1) a reduced growth rate in length of the mandible, 2) a

vertical direction of growth of the condyle, and 3) the backward eruption of the dentition. The vertical direction of growth of the condyle was claimed to have the greatest effect. A retarded maturation of the mandibular third molar was also related to impaction.

Further reports have been published from the Burlington, Ontario, Longitudinal Growth Study. Now in its eighth year, this longitudinal cephalometric study under the auspices of the University of Toronto has produced a few interesting papers. Notable are those by Hatton which deal with the rate of movement of unerupted teeth and the inheritance of features of dental eruption. Cephalometric standards for various age groups, three, six, eight and ten years have been established. The standards are in the form of dispersal of points around the mean measurements. Thus there is some interpretation of individual variation in growth.

Perhaps one of the most important papers of recent years was that of B. Lindegard entitled, *Variations in Human Body-build*. Lindegard was searching for a method of describing body-build and included in his investigation x-ray cephalograms. Of importance to the orthodontist were measures of body build showing correlation to measurements in the craniofacial region. Lindegard recalled patients, of whom Bjork had recorded cephalograms in Vasteras, applied somatic measurements and took body-build photographs. On the basis of the division of body-build into bone, muscle and fat tissues, Lindegard reported a bony length factor (for example, radius length and tibia length) indicative of endochondrally-formed bone and a sturdiness factor (for example, breadth of the femoral condyle) indicative of appositionally - formed bone.

Many correlations between facial measurements were made including the correlation between the freeway space and facial form. In this latter respect a more parallel mandibular plane angle to S-N was reported to be correlated with a wider freeway space.

Although some of the correlations were weak, Lindegard pointed out that the predominance of either the length factor or the sturdiness factor showed some relationship. Thus "a large length factor is seen in association not only with a weak cranial base bend (wide cranial base angle) but also with a long mandibular base and a large upper face height, both anterior and posterior heights. A large sturdiness factor is related to large lengths of the cranial (S-N) and mandibular bases as well as of the upper and lower face. Thus the anterior cranial base length, the mandibular base length, the length of the maxillary body, the maxillary protrusion (sella to ptm) and the alveolar prognathism are, as a rule, large in the presence of a large sturdiness factor".

A short paper by Bjork on *Bite Development and Body Build* brought Lindegard's work to the attention of the orthodontist. Bjork extended the use of body-build examination by comparing body-build to the dental arches. He inferred that skeletal sturdiness would be accompanied by dental arches big in all dimensions and with large teeth in both jaws. Slender skeletal structure seemed to Bjork to be related to a relatively narrow maxillary dental arch compared to the mandibular arch. There was also a positive relationship between body-build and tooth eruption in that earlier eruption was associated with skeletal sturdiness. Bjork went one step further and analyzed the body build of patients under orthodontic treatment with bite plates. He checked the progress of treatment by the use of cephalograms and reported a sig-

nificant difference in response to treatment, the sturdily built children responding more rapidly. In order to compare alveolar response to treatment a small portion of alveolar bone was removed from members of each group. Histological examination showed a difference in periosteal bone growth.

In 1956 many papers at the European Orthodontic Society meeting dealt with the problem of body build and facial typing. There were notable papers by Autissier, Muzi and Berger. Despite the diversity of body-build classification and different treatment procedures there was evidence that the orthodontist could benefit by examining the whole child.

With this interest in mind it was of some importance to consider the factor of growth with its effect on somatotype or body-build. One of the most interesting texts recently published is that of J. M. Tanner entitled *Growth at Adolescence*. The book is devoted to a study of the developmental changes occurring in children during the period in which we orthodontists are treating. All aspects of the child were considered and it is commendable that longitudinal data from cephalometric studies in the United States had been incorporated. Although it may be subjective, the maturation of the soft tissues of the face was presented.

Tanner was fortunate in being able to secure body measurements of adults which had formerly been somatotyped as children. With this data prediction of adult size could be made from that of the child. It was significant that prediction from the four to six year old group was more accurate than prediction during the pubertal period. Of course, after puberty prediction became quite accurate. This led Tanner to conclude that if one plotted a growth curve for a child the period of puberty became a period of disturbance and the child eventually returned to the regular curve of growth.

That the pubertal period indeed upset growth curves was shown by Nanda who published in detail in the German literature. As you may remember, Nanda showed maximum growth rates of the various facial dimensions occurring at different times relative to the circumpubertal maximum in body height. He concluded that growth of the face had its maximum circumpubertal amount slightly later than that for the general body height.

The possibilities for applying biometrical methods to longitudinal data were well presented by Tanner. In the Northcroft Memorial Lecture to orthodontists, Tanner showed the applicability of formulae to resolve the question of prediction of facial growth. He suggested that improved biometrical formulae devised by Medawar and others may be applied to the longitudinal data available in the United States. By this means significant deviations in facial growth could be detected and have predictive value. To this reviewer it seems as though a thorough survey of the significance of the craniofacial landmarks and measurements in current usage would be the first step. It is equally obvious that a coordinate system involving linear measures is the only practical means of applying growth equations.

Orofacial Musculature

There has been an increasing interest in the influence of the facial muscles and mechanisms of deglutition on the dentition. Following the tradition of Rix, Gwynne-Evans and others, it is not surprising that Tulley applied electromyographic techniques to the facial musculature and the mechanism of swallowing. In 1957 Tulley reported the activity of the labial musculature

in the chewing of various types of foods. In normal occlusion the chewing of a biscuit led to little lip activity on deglutition, but when a piece of orange was chewed and swallowed there was considerable lip activity. In cases exhibiting a malocclusion there was excessive circumoral activity.

It seems to this reviewer that two very interesting papers on the lips have been by-passed in the field of electromyographic research by orthodontists. In a paper entitled *Facial Reflexes* and a later paper *Perioral Reflexes* Kugelberg and his associates have studied reflex contracture of facial muscles from light tapping. Although the neurological mechanisms involved are not completely understood, the resultant contracture of the perioral muscles varied in the few patients reported. Reflexes were observed in the mentalis muscle together with the orbicularis oris. The variants in response would seem to be of significance to the orthodontist.

That the perioral musculature has pronounced variation in the spatial arrangement of its muscles has been well shown in the Japanese lips by T. Namiki. In careful dissection of the lip area of twenty-seven cadavers Namiki has shown the tremendous variations of the insertion of zygomaticus major and triangularis to the orbicularis oris muscle. It is presumable that similar variation exists in occidental lips.

In order to answer the question as to whether the teeth are in contact during deglutition and mastication Posselt applied a layer of wax over the lower teeth and then applied an electromyographic technique to the masticatory muscles. The wax was examined for perforations. It was found that most patients make contact with the teeth during deglutition and mastication; that the position of the contact was in the habitual closure position of the mandible (rather than terminal hinge position); and that the mandible did not seem to make any gliding movements but moved directly to the intercuspal position.

Movements of the mandible and the anatomy of the temporomandibular joint have been the fields of investigation of Murphy in Australia. Using a comparative anatomical approach and examining the path of wear of the human dentition and TMJ, Murphy concluded there was pressure transmitted through the joint. In evidence of this pressure he showed anterior and posterior facets in the glenoid fossa which coincide with an anterior and posterior facet at the head of the condyle. Murphy suggested these are functionally separate areas. Thus on the side of function the anterior facet of the condyle was against the anterior facet of the glenoid fossa; on the pivotal side the posterior facet of the condyle was against the posterior facet. This latter facet was supplied by the postglenoid process. The pivotal side was pre-set and held in place by action of posterior temporal fibers.

Fundamental to muscle is its ability to grow as the facial skeleton grows. Thus it was of interest to note Symons' paper on *The Attachment of the Muscles of Mastication.* Symons divided muscle attachments into those applied to the periosteum and those with a tendon insertion into bone. Muscles with tendonous insertion were investigated in the fetal period. It was found that continual adjustments of breakdown and restoration of tendon fibers, and bone resorption and deposition were the means of adjusting during the period of growth.

Of perhaps a more fundamental nature was Crawford's study of muscle growth. His experiment was devised to alter the distance through which a muscle had to contract in order to produce its normal degree of movement, with the intention of determining whether

this lead to any alteration in the extent of its ultimate growth. Young rabbits were used and the normal amount of growth determined by exposing the muscle (tibialis anterior) and placing ink marks or passing fine wire through the belly of the muscle. In the latter case serial x-rays showed the positions of the wires; it was found longitudinal growth occurred throughout the length of the muscle belly.

The muscle action was lengthened by cutting the crural ligament and permitting the tibialis anterior to work through a wider range of movement. After twelve months growth the normal muscle and lengthened muscle were compared. It was found that the tendon on the operated side was shorter than normal and the muscular belly greater. Thus the length of the belly of muscle was increased from the greater distance in which it had to contract.

Whether similar occurrences take place in the masticatory musculature is perhaps debatable, but the possibility of lengthening muscle is of interest in bite-opening procedures.

Cephalometrics

In 1954 Bjork wrote an excellent compilation of our present status in cephalometric roentgenology. Since that time there has been an increased usage of cephalometrics by the clinician. Numerous analyses have been devised, the most notable being that of Korkhaus. Another was that described by Schwartz which dealt not only with the bony profile but also took into account the distribution of the soft tissue. In Italy the cephalometric analysis of Muzi included the inclination of the forehead as it influenced the interpretation of the profile.

Needless to say these individuals, using different landmarks, have created a degree of confusion in definition and terminology. It was not surprising to find the European Orthodontic Society, in 1956, setting aside a subcommittee under the direction of Bjork to assess and evaluate cephalometric planes and landmarks. About the same time the French orthodontists convened for a similar purpose and clearly defined about ten craniofacial landmarks. Although the definition of landmarks may tend to arrest the progress of cephalometric research, the clarification of points and planes certainly assists the clinician.

As well as the growth studies which have been mentioned above, the field of cephalometrics has been applied to anthropology. In 1957 Sarnas published a cephalometric analysis of growth changes in ancient man in North America. He compared the growth of a selected series of Indian skulls, grouped by dental age, with Swedish and Australian native groups. Many features of the ancient Indian were common to either the Swede or aboriginal living today.

Recently the relationship of head posture and cephalometrics has been investigated by Bjerin. In an attempt to establish some standard of head balance Bjerin took cephalograms and oriented head photographs of thirty-five subjects in both standing and sitting positions. He found great variation in the inclination of the Frankfort horizontal to the true horizontal and considered that the posture of the head should be accounted for in any profile analysis.

As an extension of the metallic implant technique devised by Bjork and reported earlier in this paper, Lager reported on the effects of orthodontic treatment by superposing cephalograms on metallic implants placed before starting treatment. Thus lateral cephalograms and implants served to show tooth movements as a consequence of orthodontic treatment.

Clinical Research

Largely due to the influence of Begg, most orthodontists in this country are now aware of the effects of light forces in orthodontic treatment. However, behind Begg's work was the research of Storey in Australia. In an enlightening series of papers he reported bone changes in experimental animals. Storey applied different amounts of force to the incisor teeth of rodents. He found that there was an optimum range of force for each species. Of orthodontic importance was the observation that this optimum range of force may be determined for the human to produce the maximum rate of tooth movement. Storey also observed the effects of the duration of forces on the teeth and suggested that light, continuous forces be used with periods of rest so that bone may be reformed ahead of the tooth. It was observed that new bone formation occurred at a slower rate than bone absorption. Lastly, Storey observed the effect of sex and age on tooth movement. As would be expected, there was a decrease in the rate of bone resorption with increasing age.

In two clinical papers Smith and Storey offered the suggestion that the usual force employed to retract cuspid teeth was such that "undermining resorption" occurred on the cuspid and "physiologic tooth movement" at the molar. Thus there was a tendency for the molar, due to its larger root area, to move mesially more rapidly than the cuspid moved distally. They offered the possibility of forces light enough to be "physiologic" at the cuspid and practically negligible at the molar.

This same general feeling was echoed by Reitan in a discussion of the forces in orthodontics. He suggested light forces for the initial movement of the teeth. He did mention that greater forces may be necessary in the final positioning of the teeth due to the tension of the fiber bundles.

The effects of these gingival fibers on the rotation of teeth has been shown by Reitan. Some of this paper has recently been published in the American literature. Of particular significance was the long period of retention required to permit adaptation of the marginal fibrous tissue.

In the recent European literature considerable emphasis has been placed on the rapid expansion procedures in the maxilla. In 1956 Derichsweiler reported good results in a large number of cases treated by expansion. Later he reported experimental expansion of the median palatal suture in the macaque monkey. He varied the rate of expansion and found that slow (or biologic) expansion had little effect on the palate. On the other hand rapid expansion resulted in emergency bone deposition in the region of the nasal septum and six months later the area appeared normal.

A clinical paper by Gerlach showed that there was an increase in the human apical base after rapid expansion. His method of examination was similar to that used by Howes and concerned gain in width of the apical base.

One of Bjork's students, Krebs, has adapted the use of metallic implants to determine the effects of rapid expansion procedures in orthodontic treatment. Implants were positioned on the infrazygomatic ridge and in the palate, lingual to the cuspids. It was assumed that the former implants would show separation of the maxillae while the latter the expansion of the alveolar ridges. Frontal, lateral and standard occlusal roentgenographs were taken. Although only one case was reported, it was found that the dental arch was increased in width more than the basal arch and that there was a tendency of the basal arch width to lessen during

the period of retention.

That arch length may be influenced by the premature extraction of deciduous teeth was shown by Clinch on longitudinal data extending over an eleven year period. Casts were taken at annual intervals between three and fourteen years of age. She concluded "that extractions before the eruption of the first permanent molars resulted in permanent loss of space, but to a varying degree and more in the upper than in the lower arch; secondly, that well-developed arches showed little, if any, permanent space loss following later extractions".

The last area which I would like to comment upon is that of the treatment of the cleft lip and palate patient. In 1954 McNeil published on the early orthodontic management of these patients. Although there was considerable controversy concerning the effects of this treatment on the arch form of the cleft palate patient it was of some value. By 1958 Burston reported on the use of the McNeil technique. Much of the paper was a review of the embryology of the oral cavity and a discussion of the role of the nasal septum during the fetal period; however, the effectiveness of early treatment was well shown in a series of patients. In brief, McNeil's objective was to place the maxillary segments in such a position that the surgeon could readily close the lip. This avoids the typical collapse of the maxillary arch. Treatment was instituted as soon after birth as possible by a series of removable plastic appliances.

In 1958 Derichsweiler reported on the application of McNeil's work to the early cleft palate patient presenting favorable results. This year a further report by Hotz and Graf-Pinthus has shown the effectiveness of McNeil's procedure before lip surgery.

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Function And Growth

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The objective of moving teeth orthodontically is to establish a satisfactory esthetic and functional occlusion. We wish this occlusion to be associated with a pleasing facial contour and we wish it to be relatively stable but, more than this, we should desire that it be in functional harmony with the two temporomandibular joints and the musculature. The time relation of the therapy and facial growth dictates as to when the satisfactory occlusion is attained — presuming, of course, that the therapy is adequate. Recognizing the clinically demonstrated fact that facial growth and favorable growth increments of the facial components shortens the time of treatment and enhances the result attainable, the opposite is likewise so.

It is not a new opinion that orthodontic treatment does not promote growth of the mandible and maxilla, excluding the alveolar process. Again the opposite is so, that therapy does not inhibit growth. If the antitheses of these tenets were true and the orthodontist by therapy could promote or inhibit facial growth, the proportion of seemingly desirable results would be increased many fold. Individual cases are offered from time to time as evidence that growth had been influenced but these are countered by those in which the same therapy did not produce a similar "response". The response, or rather the association of growth and therapy, is entirely too variable for one to assume that therapy influences growth.

In further consideration of growth, the working hypothesis set forth in this paper is that, while favorable incremental and directional growth of the facial parts is our ally in treatment, continued growth subsequent to treatment is our functional foe. Specifically, continued mandibular growth at a greater rate than maxillary growth — desirable as it is in the correction of malocclusion — may be a functional detriment later on two counts, viz., abnormal temporomandibular joint function and traumatogenic relations of the teeth. This hypothesis is documented as fact, at least in part, by the following orthodontically-treated cases selected on the basis of disharmonious function of the parts of their respective stomatognathic systems.

This paper is a further extension of the functional concept set forth in two previous publications, *"Concepts Regarding Function of the Stomatognathic System"* [1] and *"Function — The Neglected Phase of Orthodontics"* [2]. The method of functional analysis and a more detailed description of the abnormal functional conditions of the stomatognathic system as outlined in these publications will not be repeated here but rather attention will be focused toward the conflict of favorable growth and abnormal function.

Case R.T. (Figure 1) was a Class II, Division 1 malocclusion. In the deciduous dentition the SNa (Sella turcica-Nasion - Point a) and SNb (Sella turcica-Nasion - Point b) difference was -11°, that is, SNb was 11° less than SNa. The evaluation of SNa at this age was not accurate as the anterior portion of the maxilla was contoured by the unerupted permanent incisors.

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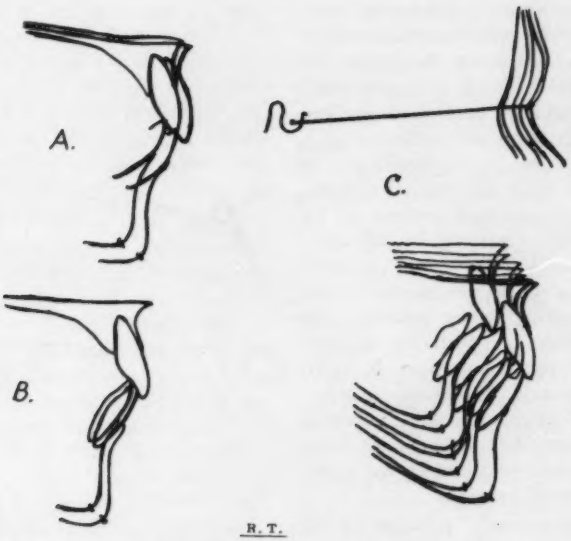

Fig. 1 A. Composite tracings of maxilla at ages fourteen years, ten months and seventeen years, eleven months superimposed on the SN line at point S.

B. Composite tracings of the maxilla and mandible at the same ages superimposed on the maxillary line to demonstrate the change in relation of mandible to maxilla.

C. Composite tracings of serial cephalometric radiographs for seven years. The two years, seven months age is not shown because of the inaccuracy of positioning the head at that age.

Note that after the eruption of these teeth the SNa value was less by 2° but that the continual reduction of the measured difference was in the mandible. The reduction from a -9° to a -6° was a favorable trend for treatment but the continued reduction to -4° was a detriment to function (Figure 1B). Extraoral therapy exerting a posterior force on the maxillary teeth was applied intermittently and not too enthusiastically from eight to ten years of age and the Class II malocclusion became a Class I. No mandibular appliance therapy was used at any time. The enlarging facial pattern with favorable mandibular growth at the time of the treatment was responsible for the correction and, had the increments been small or unfavorable in direction, the unsatisfactory result achieved under those conditions would no doubt have been attributed to poor patient cooperation. In this enlarging facial pattern simple therapy with poor cooperation achieved a moderately good result. Useful as the mandibular growth was during treatment, it produced functional disharmony in the years after treatment, particularly since it was the major area of the face that was continuing to enlarge. As the SNb continued to increase and the SNa remained the same, a traumatogenic relation of the

incisors was slowly introduced. Associated with this was the occurrence of functional crowding of the mandibular incisors. This in some measure was a protective mechanism. In addition, crepitus of both temporomandibular joints was noted. This is explained on the supposition that the incisal relation prevented the occlusal position of the mandible from assuming its full anterior position dictated by the condylar growth. This would not impede its anterior positioning at rest position; thus the condition of posterior superior mandibular displacement was initiated. The translatory movement between condyle and disc, not present normally, represents flaccidity in the joint structures that was recognized by the clinical symptoms of crepitus.

The traumatogenic relation of the incisors was recognized by the double tap heard as the teeth were occluded and by the detection of considerable incisal mobility noted by placing the fingers lightly on the maxillary incisors as the teeth were occluded and as the mandible was moved into the incision position. The patient complained of soreness (pulpitus) of these teeth. Treatment by equilibration on the lingual surfaces of the maxillary incisors and labial surfaces of the mandibular incisors relieved the acute symptoms but abnormal function is still present and restorative dentistry may be required to establish normal mandibular-maxillary functional relations of the structures.

The functional significance of greater mandibular prognathism is shown also in Case F.A. (Figures 2 and 3). Maxillary and mandibular prognathism (in relation to cranium) increased with growth but to a greater degree in the mandible. The angle SNa increased five degrees (78° to 83°) and the angle SNb increased eight degrees (75° to 83°). The mandibular change was due to

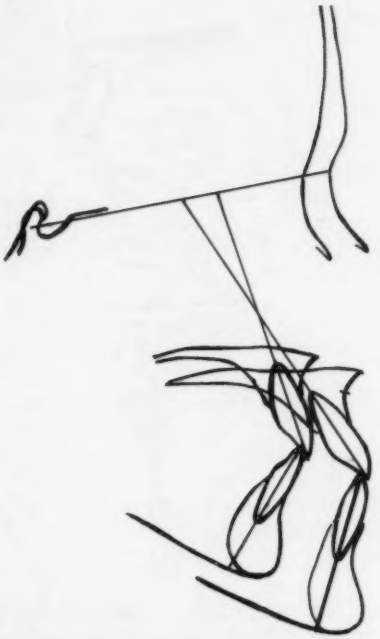

Fig. 2 Composite tracings of case F.A. at ages eight years, five months and fifteen years, four months superimposed on SN at S.

	8 yrs. 5 mo.	15 yrs. 4 mo.
SNa	78°	83°
SNb	75°	83°
Diff.	-3°	0°
1 to SN	99°	114°

growth and, possibly to some extent, repositioning during treatment. Initially the path of closure was upward and backward. As the maxillary incisors were moved labially in the first treatment period, the path changed to the normal upward and forward. The clicking and crepitus of the temporomandibular joints that was present before treatment was eliminated but, as the mandible continued to grow more rapidly than the maxilla, it returned. At the age of fifteen years and four

months, even with a normal upward and forward path of closure exhibited, the abnormal joint function was again present. Other abnormal functional symptoms were the double tap heard when the teeth were tapped together, excessive mobility of the incisors and irregular mandibular movement on opening and closing.

In this facial pattern the continued anterior movement of the mandible resulting from the continued condylar growth resulted in a traumatogenic incisal relation that was detrimental to the teeth and supporting tissues; also, the incisal function proprioceptively induced posterior displacement of the mandible with its attendant abnormal joint function. It is possible that even the true rest position as well as the harmonious occlusal position could not be exhibited because the positions occupied by the maxillary incisors, spatially and timewise, were not in harmony with the degree of mandibular growth or vice versa.

What can be done with regard to treatment? The initial labial movement of the maxillary incisors permitted the slight functional crowding of the mandibular incisors to improve and even become slightly spaced. With the later mandibular growth the mandibular incisors (without mandibular therapy) became more upright and the spacing was eliminated (Figure 3). This could not have occurred without spacing and it is probable that the present abnormal functional relation of the incisors will promote crowding once again. Equilibration on the labio-incisal area of the mandibular incisors and lingual marginal ridges of the maxillary incisors from time to time was bene-

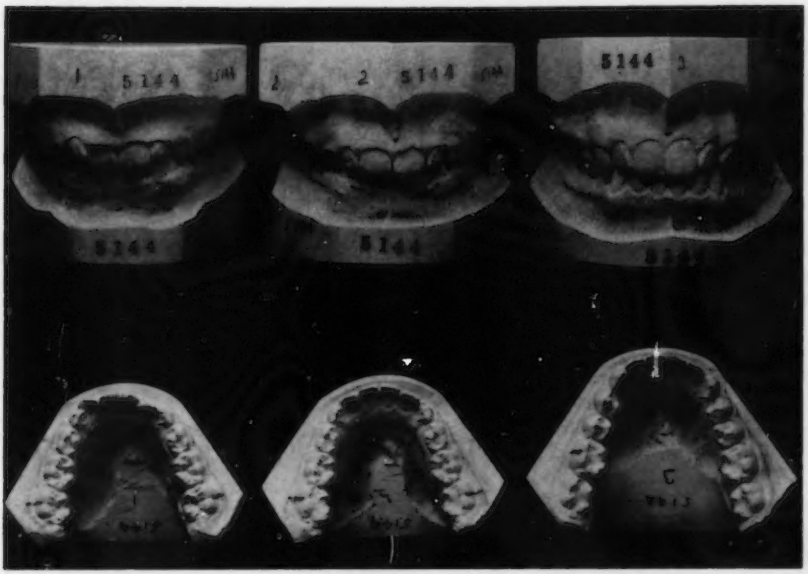

Fig. 3 Frontal views of casts and occlusal views of lower casts at ages eight years, five months; nine years, six months; and fifteen years, four months. Note the spacing that occurred between the mandibular incisors in the second cast and the reduction of the spacing in the third cast. No mandibular therapy was used.

ficial in producing a single tap and lessening the incisor mobility but this improvement was only transient and, as the mandible grew or was repositioned anteriorly, the problem recurred. Now that growth is presumed to be almost completed, a static relation of the structures insofar as growth is concerned will be attained and attention can be focused on the dynamic problem of abnormal function. Additional equilibration has been done and a diagnostic treatment splint that positions the mandible slightly downward and forward has been placed. The clicking, earaches, and irregular mandibular movement have been eliminated. The splint is quite comfortable and it is presumed from evaluation of the improved functional condition that the splint occlusal position is the desired harmonious occlusal position. The splint will be replaced by restorative dentistry in the mandibular molars once it can be assumed that growth has been completed.

The spatial placement of the maxillary incisors in relation to the mandibular incisors determined by the concurrent or subsequent mandibular growth is important. Protruding maxillary incisors may be retracted in treatment. The extent of the retraction distancewise and timewise is determined by when an assumed normal relation of the incisor teeth is attained. This is influenced by the coincidental growth activity in the total face as teeth move more favorably in an enlarging facial pattern. With particular reference to the mandible, should the variance in growth rates produce mandibular growth activity expressed by a significant increase in the angle SNb, the desired incisal relation is attained sooner than if the growth is inactive. In the latter instance the maxillary incisors would need to be retracted farther and usually for a longer period of time.

The presumed normal incisal relation desired by the orthodontist is very often the adult relation of maxillary and mandibular incisors. Actually the norm for the eight or ten year old child exhibits considerable overjet thus anticipating further mandibular growth at puberty. The true norm for the age must be the orthodontic objective but, if it is not taken into account and a contact incisal relation is created at say the age of ten, function, while it may be satisfactory for the moment, may become abnormal as mandibular growth occurs and incisal interference may develop. If so, a double tap is heard as the teeth are tapped together and they can be felt to move excessively. The proprioceptive stimuli maintains the occlusal position but, as the mandible is enlarged and cannot be positioned forward, the upward and forward path of closure from rest to occlusion is changed to an upward and then to an upward and backward path. Clicking and crepitus of the joints is introduced and the mandibular movements may become irregular. One must not expect the maxillary incisors to be repositioned labially as their position is maintained by the constant lip pressure. They must be moved labially to conform functionally with the normal mandibular position.

Case J.E. is a Class II, Division 1 malocclusion (Figure 4). The serial cephalometric radiographic data is summarized in Table 1. It must be realized that the numbers do not tell the entire story of growth and treatment. One cannot be sure whether such differences in values as 82° and 83° represent actual changes or not, despite conscientious attempts at accuracy. Furthermore, if such a change is actual, one cannot be certain as to what it means, viz., whether it is a change in the dental area or a change in the line of orientation. The interpretations

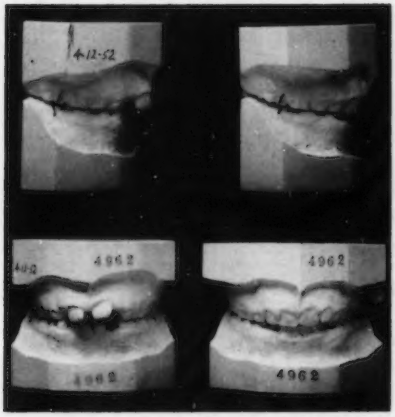

Fig. 4 Case J.E. Lateral and frontal views of casts before and after first period of treatment.

made here are with full awareness of the limitations of the technic and of the individual making its application and interpretation.

In contrast with R.T. who was treated similarly with extraoral therapy at a comparable age, no significant change occurred in the mandibular maxillary relation. In R.T. there was little maxillary incisor change but considerable mandibular change; the significant change for J.E. was in the maxillary incisor position.

In J.E. extraoral therapy applying a distal force on the maxillary second deciduous molars and a lingual force on the maxillary permanent incisors was started at eight years and three months (Table 1, column 1). A Class I tooth relation and reduction of most of the overjet was accomplished in one year. The maxillary incisor change is evident by comparing columns 1 and 2. The incisors are more upright and have been retracted. Some overjet was permitted to remain but during the next year, as spacing developed between the incisors as they inclined slightly to the labial (columns 2 and 3), a removable maxillary retainer was placed to close the spaces. This was accomplished but the overjet was eliminated. The question now arises as to the influence of the incisal interference on the position of the mandible. It was at this time that abnormal function, evidenced by clicking and crepitus of the joints, facial pain, irregular mandibular movement and jiggling and excessive mobility of the incisors, was noted. Steps were taken to correct the functional problem and a maxillary lingual arch appliance with auxiliary springs was placed to move the incisors labially since there was not sufficient self adjustment following elimination of the retaining appliance. The incisors were inclined labially to a 95° inclination to sella-nasion line (column 5). At thirteen years, nine months the abnormal functional condition was still present; therefore, maxillary incisor bands were

TABLE I

	1.	2.	3.	4.	5.	6.	7.	8.	9.
	8 yrs. - 3 mos.	9 - 3	10 - 2	11 - 1	11 - 10	13 - 4	13 - 9	14 - 4	15 - 8
SNa	83°	82°	83°	83°	82°	83°	83°	82°	83°
SNb	76°	75°	76°	77°	76.5°	77°	78°	77°	78°
Diff.	-7°	-7°	-7°	-6°	-5.5°	-6°	-5°	-5°	-5°
1 to SN	109°	90°	94°	91°	95°	92°	93°	99°	94°
1 to NP	9 mm.	4 mm.	6 mm.	5 mm.	5 mm.	5 mm.	5 mm.	5 mm.	5 mm.

Data compiled from serial cephalometric radiographs for case J. E.

placed to move the incisors labially to the angulation of 99° (column 8).

For J.E. the maxillary incisors had been moved too far to the lingual with elimination of overjet. The case had been overtreated and future mandibular growth had not been taken into account.

The congenital absence of one or both maxillary lateral incisors alters the position assumed by the central incisors from that which would have been attained by growth if all incisor teeth had been present. The central incisors are found to be more upright and lingually positioned. This is mutilation of a dental arch by nature with its attendant growth retardation. As the mandible continues to enlarge the maxillary incisor position invariably interferes proprioceptively with the forward positioning of the mandible in response to its growth. When this abnormal functional condition is introduced depends on the time relation of the incisor position and mandibular growth. The path of closure from rest to occlusion may be observed to change from an upward and forward to an abnormal vertical and then to an upward and backward path. Associated with this may be clicking and crepitus of the temporomandibular joints; pain may also be introduced. An abnormal pattern of incisal attrition on the lingual marginal ridges of the maxillary incisors and labial incisal areas of the mandibular incisors can be observed. The protrusive functional wax pattern will be perforated markedly and in the incisive movement the maxillary incisors can be felt to move more than normally.

At one time there were two choices as to treatment of these cases, viz., to close spaces or to open them and restore the missing teeth. Now that function of the entire stomatognathic system is taken into account in treatment planning, there is only one plan of treatment — to open spaces and place the maxillary incisors in positions that permit normal function.

In case B.L. (Figure 5) the maxillary lateral incisors were congenitally absent. The abnormal functional conditions of clicking and crepitus of the joints, jiggling and excessive mobility of the incisors was present in this instance before treatment. The angle of the maxillary incisor long axis to the SN line was 89° before treatment and 100° after treatment. This change was brought about by labial tipping of the

Fig. 5 Case B.L. Composite tracings of cephalometric radiographs at ages thirteen years, four months and sixteen years, seven months.

	13 yrs. 4 mos.	16 yrs. 7 mos.
SNa	83°	83°
SNb	77°	79°
Diff.	-6°	-4°
1 to SN	89°	100°

incisors. With the creation of the overjet or horizontal overlap the mandible moved downward and forward without the use of elastics. As this occurred the abnormal functional symptoms of clicking and crepitus of the joints were eliminated. The path of closure from rest position to occlusal position changed from an upward to an upward and forward path. Since there was no significant cranial and maxillary growth in the treatment and retention periods, the forward and downward movement of the mandible can be assumed, at least in a large measure, to be repositioning on a proprioceptive rather than growth basis, particularly since it was accompanied by an improvement in joint function.

In such cases as B.L. function may be satisfactory at an early age but, as the mandible continues to enlarge and is not permitted to be repositioned forward in response to the condylar growth by the proprioceptive stimuli of lingually-positioned central incisors, a posterior displacement develops. When this occurs depends on the variables of the maxillary incisor position and mandibular growth. Naturally this is individualized for each subject. Going hand in hand with the developing posterior displacement is the occurrence of an abnormal incisal attrition pattern, increased incisal mobility, sensitivity of the incisors and abnormal joint and muscular function.

In the mind of the writer, considerations of function are modifying the time or age for treatment of malocclusion of the teeth. At present the general rule is to treat functional problems early and structural problems late. Furthermore, there is less desire to mutilate the dental arches by early removal of deciduous or permanent teeth. The predictions of future growth are far too general to apply specifically to an individual, and early attainment of assumed normal occlusion and assumed normal facial esthetics are not sufficient criteria for evaluation. Function must be foremost in our thinking.

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